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# Metals and Alloys

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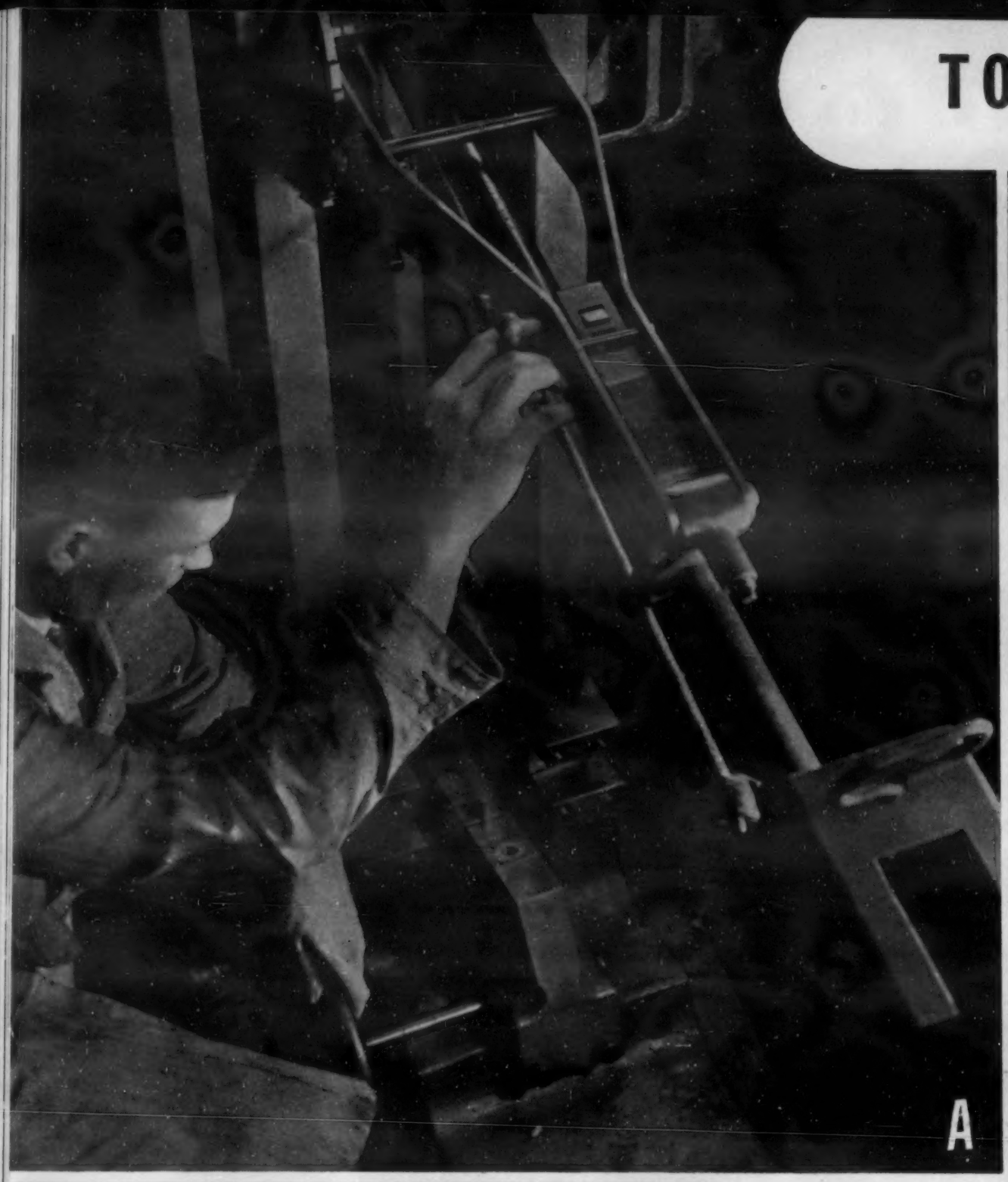
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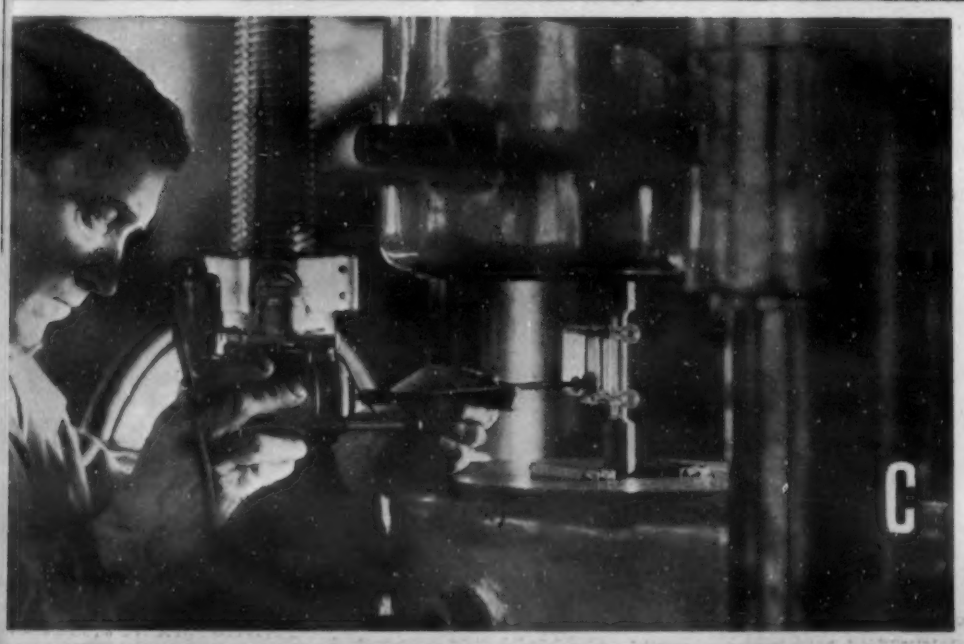
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**(A)** *Testing toughness of steel by breaking it in an impact machine.*
**(B)** *Testing the behaviour of steel under repeated alternating stress in fatigue machine.*
**(C)** *Taking exact measurements of strength and elastic properties with an extensometer.*
**(D)** *"Guillotine" test for determining resistance to drop impact.*

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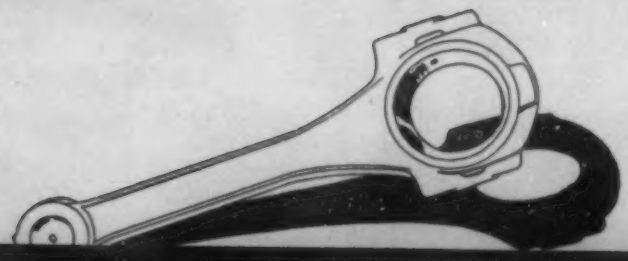
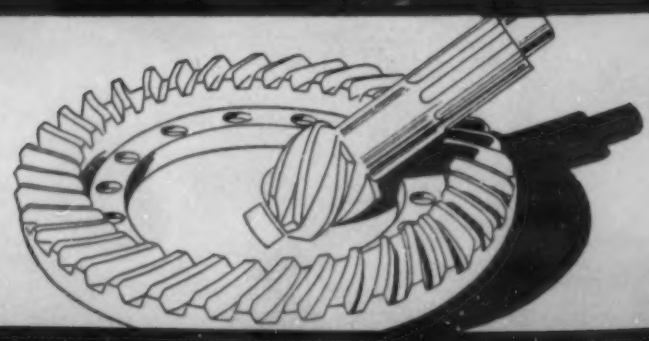




# Trends in Refractories for the Basic Open-Hearth Furnace

## Part I

**BY R. P. HEUER**

*Vice President,*
*General Refractories Co.,*
*Philadelphia.*

*The author of this article, who writes with authority, discusses the substitution of basic brick for silica brick in the roof and other parts of an open-hearth furnace. He states that a basic roof for a basic open-hearth furnace is a logical combination and that recent developments have been made in refractories which "warrant serious consideration of the basic roof problem in the steel industry."*

*Our editorial advisory board pronounced this article "very accurate, very fair" and stated "that it correctly represents an important trend."—The Editors*

THE BASIC OPEN-HEARTH FURNACE has been used in commercial steel production for more than 50 years. During that time the design and operation of the furnace have shown continuous improvement. The size of the charge has been increased many fold. The handling of materials to and from the furnace has been fully mechanized. Various types of fuel have been introduced to obtain improved combustion control, faster melting and better B.t.u. economy. The metallurgy of the basic refining operations has been brought under strict supervision using the principles of modern physical chemistry. But during most of these changes the only thing basic about the furnace itself has been the melting hearth. The rest of the furnace, namely the roof, front walls, backwalls, bulkheads, ports, downtakes, slag pockets and occasionally top courses of the checkers have been built of silica brick. The original choice of silica as the principal refractory in the basic open-hearth furnace was made with the following facts in mind: (1) that silica brick were relatively inexpensive and capable of withstanding the basic conditions with surprisingly good results; (2) that basic brick were expensive and incapable of proper application due to their poor spalling resistance and other physical defects.

### Some Shortcomings of Silica Brick

The shortcomings of silica brick for open-hearth use can be traced chiefly to the low melting point of silica (1710°C., 3110°F.) and the ease with which it can be fluxed by basic oxides. In the basic open-hearth furnace the melting process forms oxide dusts from the charge which are carried around to all parts of the furnace system. An important constituent of these dusts is a "fume" of very fine particles, some almost colloidal in size and composed essentially of iron oxides. This fume probably originates from the vapors given off by the molten metal which oxidize and condense to form small droplets of oxide in the gas stream. These oxide fluxes later combine with the silica of the roof and sidewalls to form a slag which soaks into the porous brick structure. This slag first saturates the brick and then begins to drip off into the bath or wash down the sidewalls. According to Sosman,[1] silica brick are worn away in normal operation a few hundredths of an inch per heat, or less than a tenth of an inch per day. If the furnaces are overheated, however, "dripping" takes place at an accelerated rate with rapid loss of refractory. A "drip" from a basic open-hearth furnace roof analyzed by Larsen and Schroeder[2] contained 40.1 per cent iron

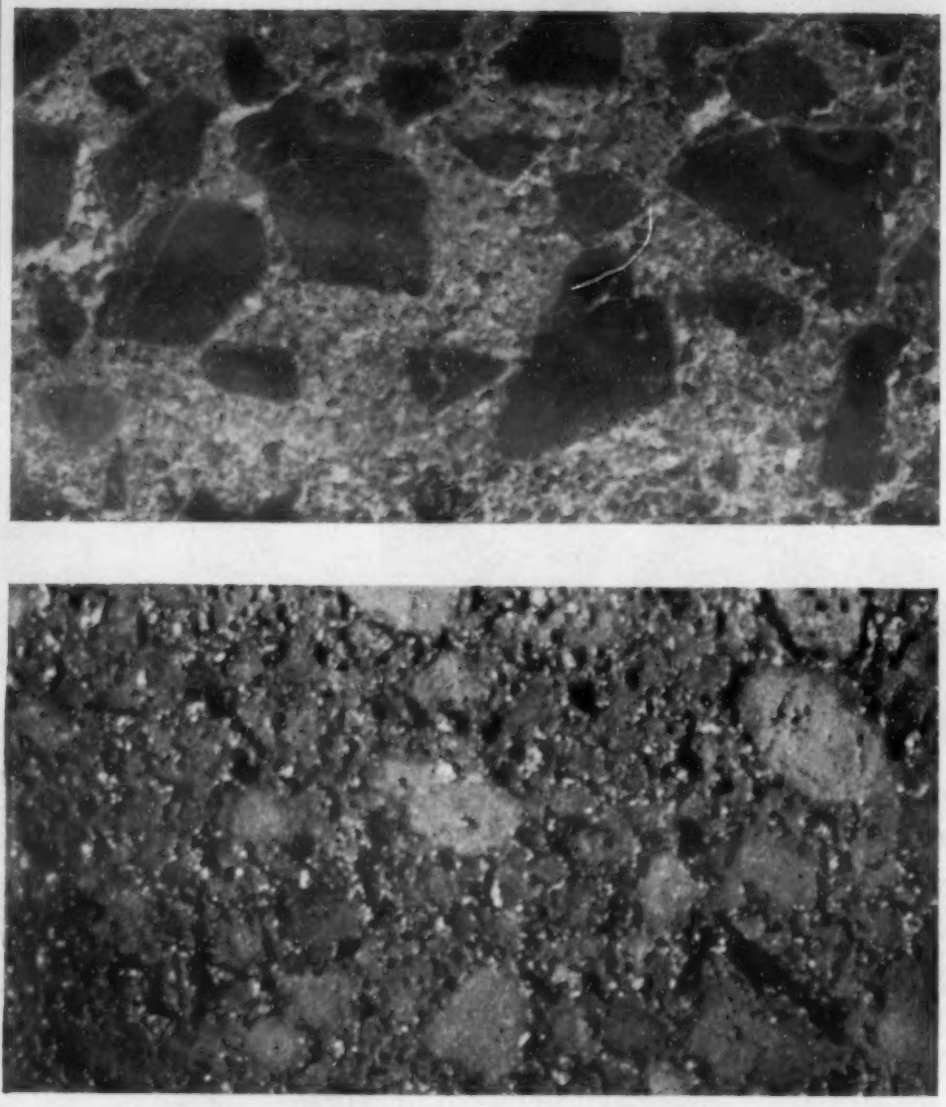


*Fig. 1. Polished sections of chrome brick magnified 5 to 6 diameters. Top, a chrome-magnesite brick molded under high pressure from gap-sized particles. Bottom, a straight chrome brick with continuous sizing and conventional forming pressure.*

oxides, the remainder being silica. The melting point of this "drip" was below 2372 deg. F.

The question arises why silica brick last as long as they do when operated at temperatures so much higher than that given above. The answer is due partly to the large percentages of FeO which can be absorbed by $SiO_2$ without appreciably decreasing its melting point. This is caused by the immiscibility of the silicate liquids in the $FeO$-$SiO_2$ system. There is also the fact that much of the iron oxide may be present as $Fe_3O_4$. Larsen and Schroeder, as well as McCaughey,[3] have pointed out that magnetite is the chief oxide constituent in open-hearth roof brick where the prevailing atmosphere next to the roof is oxidizing. Magnetite is apparently in equilibrium with the cristobalite and tridymite of the brick up to nearly 2975-3000 deg. F., though Sosman states that 3000-3090 deg. F. is the dead-line for safe operating temperatures of an iron oxide bearing silica roof.

## Basic Brick

About ten or more years ago refractories manufacturers began to realize that basic brick, due to their higher melting points (500°F. or more in excess of silica brick) offered a solution to the problem of better refractories for the basic open-hearth furnace provided the physical characteristics of the brick could be improved. Prior to that time basic brick can be produced to overcome these de- or chrome ore by molding the ground material into brick form, usually without added bonding substance and burning to about 1450 deg. C. (2642°F.) in kilns. The products thus obtained spall very badly when used as a substitute for silica brick. The brick are lacking in strength at high temperatures and have other serious physical defects.

Extensive research work has shown that improved basic brick can be produced to overcome these defects. New compositions are now available containing mixtures of chrome ore and magnesite which are vastly superior for basic open-hearth uses to the former brick composed of straight chrome ore or magnesite. These mixtures vary between the limits of 80 parts magnesite and 20 parts chrome to 80 parts chrome and 20 parts magnesite. For certain specific uses a mixture higher in chrome ore is desirable, for other uses a mixture higher in magnesite is preferred.

Studies made by means of the petrographic microscope on the structure of the brick both before and after use give ample reasons for the relative superiority of these improved brick. These studies of the internal structure show also that the size of the particles used in making the brick is of even greater importance than the percentage of chrome ore and magnesite used. In the preparation of the ground material formerly used for making basic brick, it was customary to pass the products of the grinding mill over a single screen having, for example, an equivalent in standard testing sieves of 20 mesh per linear inch with a mesh opening of 0.0328 in. All the particles passing through this screen were used in making the brick. In such a product there is present a continuous grading of particles from the very largest size just capable of passing through the screen to the very smallest which the mill is capable of producing. The relative amounts of the various sizes present cannot be closely controlled by the use of a single screen since the distribution of the sizes present is a function of the hardness of the particles and the action of the grinding mill used. To proportion properly the various particle sizes it is desirable to use a series of three screens. The sizes of these screens vary according to different conditions. A typical series might consist of the equivalent of a 6-mesh standard screen, a 20-mesh and a 60-mesh. By grading the ground product with these screens,

three bands of sized particles are obtained—a coarse band through 6-mesh and on 20-mesh an intermediate band through 20-mesh on 60-mesh; a fine band through 60-mesh. Properly balanced mixtures, depending upon specific requirements, are made by taking 55 to 70 parts by weight of coarse particles and 30 to 45 parts of fine particles. The intermediate particles are rejected or their use is kept to a small amount not exceeding 10 parts.

## "Gap-Sizing" and Grain-Sizing

This type of particle control is called "gap-sizing" to distinguish it from the older type of continuous grain-sizing because of the gap produced in the continuous grading by the removal of the intermediate sized particles. Using this method, the ratio of coarse to fine particles is accurately controlled by mixing the required weight of each band of sized particles. Thus the undesirable variations in the amounts of coarse and fine particles, which are present in continuous grain-sizing, are avoided. The lack of intermediates and the closely controlled ratio of coarse to fines in gap-sized mixtures enables the particles to pack together properly when the brick are formed. This is very important if good physical properties are to be obtained in the brick.

In order to obtain the best packing of the sized particles in the finished brick it is desirable to form the brick under the maximum forming pressure. By using presses capable of exerting 10,000 lbs. per sq. in. pressure on the brick, the gap-sized particles are molded together in very compact form. Fig. 1 shows a polished section of a chrome-magnesite brick prepared in this way. For comparison a straight chrome brick made with continuous sized particles under conventional forming pressure is also shown. The fine particles of the gap-sized brick fill the interstices between the coarse particles and yield a dense mass which is both strong and resilient. The increased strength thus obtained makes it possible to produce brick without the conventional burning in kilns. Refractory bonding substances are added to the brick mixture. Upon drying, the brick develop a crushing strength which equals or exceeds that obtained by burning in kilns. The properties of typical basic brick made with the foregoing improvements are shown in the table.

These improved properties, especially the spalling resistance, make the brick suitable for use instead of silica in most, if not all parts of the furnace above the floor level. In front walls, backwalls, monkey walls, ports and downtakes, they are vastly superior to silica brick. They give sufficiently longer life to offset their higher first cost. Especially is this true in furnaces where the production rate is kept at a maximum by charging a larger heat than that for which the furnace was designed. Under such conditions the basic brick are not so sensitive to local overheating as are the silica brick. Thus the furnace can be driven harder without damaging the lining. There is, however, a maximum driving rate which is determined by the ability of the silica roof brick to stand up. Premature failure frequently shows up in the roof shoulders along the skewbacks over the backwall and to lesser degree over the front wall. The brick in these places burn through and require replacement while there is still considerable life left in the major portion of the roof. Repairs can be made but valuable time is lost in shutting down the furnace and such repairs to a standing roof cannot

TABLE OF PROPERTIES OF TYPICAL BASIC BRICK

| | Ritex Magnesite Per Cent | Ritex Chrome Per Cent |
|---|---|---|
| CHEMICAL ANALYSIS: | | |
| Ignition Loss | 4.71 | 2.85 |
| $SiO_2$ | 5.48 | 5.05 |
| $Fe_2O_3$ | 1.94 | 1.61 |
| FeO | 2.70 | 10.59 |
| $Al_2O_3$ | 5.80 | 17.50 |
| CaO | 1.70 | Trace |
| MgO (by diff.) | 70.51 | 32.26 |
| $Cr_2O_3$ | 7.16 | 30.14 |
| BULK DENSITY: | | |
| Grams per c.c. | 2.95 | 3.18 |
| Oz. per cu. in. | 1.71 | 1.84 |
| PORE SPACE: | | |
| Open | 11.50 | 8.58 |
| Closed | 0.00 | 0.00 |
| Total | 11.50 | 8.58 |
| COLD CRUSHING STRENGTH: | | |
| Lbs. per sq. in. | 8826 | 6325 |
| PANEL SPALLING TEST (Using standard A.S.T.M. spalling equipment) Bricks preheated to 1650° C. (3002° F.) and tested with air cooling from 1600° C. (2912° F.) Per Cent loss in Weight after 50 cycles | None | None |

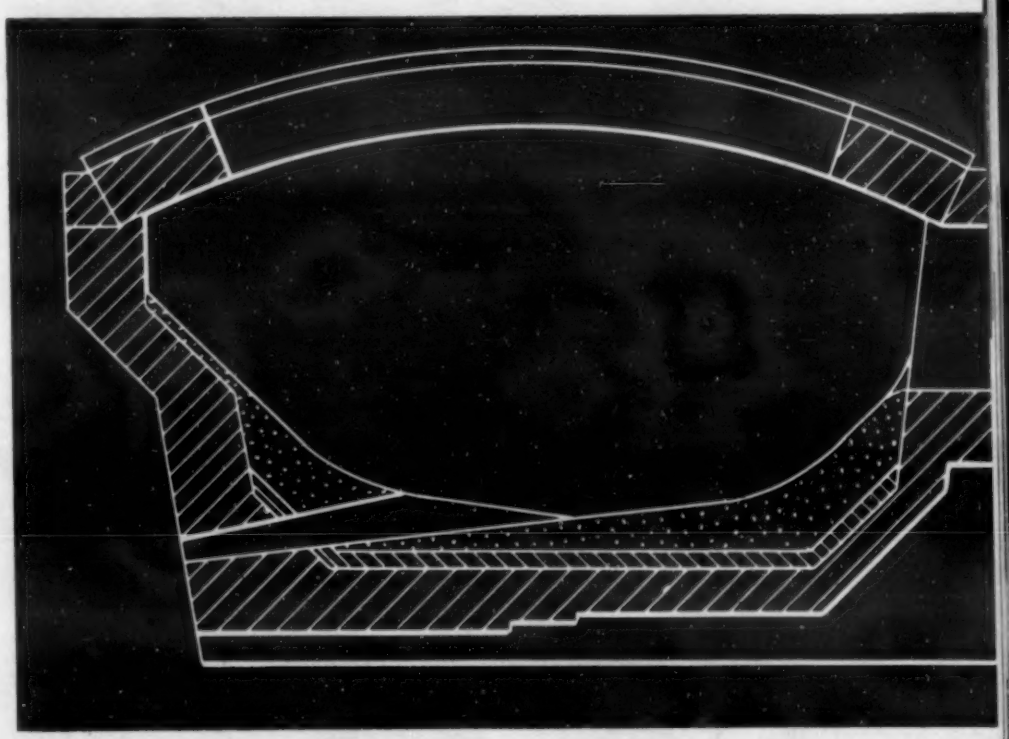


*Fig. 2. Cross section of a basic open-hearth furnace with silica roof and chrome-magnesite shoulders.*

be made very efficiently. It is possible to use basic brick to replace silica brick in roof shoulders which require early replacement. By so doing the basic brick go through a roof campaign without repair.

## A Typical Installation

A typical installation is shown in Fig. 2 for a 150-ton, oil-fired furnace. Basic shoulders of unfired chrome-magnesite are built to replace the silica for a length of 42 ft. over the back wall and front wall. Unfired chrome-magnesite skewbacks are used and the basic shoulders extend out 2 ft. from each row of skews. The roof thickness is 15 in. with 18-in. ribs on 24-in. centers. Key brick are used in the basic shoulders. The silica brick in the remainder of the arch are straights and wedges. Half of the key brick are completely covered with steel plates 1/16 in. thick. These brick are made by pressing the plates and the refractory material together to form an integral shape at the time the brick are molded.

In laying the roof these plated brick are alternated with ordinary keys molded without plates. The assembled roof has a single thickness of metal in all transverse and longitudinal joints. On the initial installation, the first campaign brought out clearly that the basic brick could be substituted for the silica and substantial economies could be effected. After 110 heats, the silica adjacent to the shoulder over the backwall required patching. The patch, however, was very much smaller than had been the case before basic shoulders were used. The time lost in patching was much less than formerly required. After 165 heats the silica roof required complete replacement and the furnace was shut down for rebuild. The basic shoulders still showed 40 per cent of their original thickness. The basic skewbacks were in excellent condition and suitable for another campaign. Final analysis of the first trial showed a 37 per cent reduction in time lost for roof repairs, a 55 per cent reduction in roof repair costs and a 50 per cent reduction in the chrome ore required for backwall maintenance. These savings more than compensated for the higher first cost of the basic brick.

On a second furnace in the same open-hearth shop the shoulder over the backwall was widened to 30 in. and the rise of the roof increased to 33 in. This furnace gave 10 per cent longer life than the first furnace. Further trials are being made on other furnaces with increasing width of the shoulders, the object being to reduce the size of the repair to the silica brick in midcampaign and ultimately to eliminate it entirely. To date six installations have been made in this shop and satisfactory performance and costs are indicated.

Petrographic examination of the chrome-magnesite brick after a campaign in roof shoulders shows the original brick structure has been completely altered at the hot working face. Some of the coarse chrome ore particles still remain. They show wide black bands at the grain borders due to absorption of magnetite. All of the fine particles in the section are opaque due to absorption or alteration by magnetite. Chemical analyses indicate magnetite to be present in amounts exceeding 25 per cent. The coarse chrome ore particles which remain intact are held together by a matrix of brownish-yellow silicates in the form of needles. Silica has been picked up in amounts exceeding 11 per cent above that originally present in the brick.

The silica probably comes from the wash of ferrous silicate which diffuses or flows down from the adjacent silica brick located higher in the roof arch. Dispersed in the silicate matrix are numerous cubical to lath shaped and dendritic black crystals of secondary magnetite. No periclase is visible. The presence of iron oxide-silica wash has caused more than 85 per cent of the magnesia originally present in the brick to have disappeared. The chromic oxide content of the brick has remained about the same as that originally present. Fusion tests on the altered section of brick remaining at the hot working face show a P.C.E. Value in excess of cone 38 (3335°F., 1835°C.). No trials were made to see how much the P.C.E. Value exceeded cone 38 but the above data are sufficient to indicate that the basic brick have not suffered any substantial loss in refractoriness because of the alterations which have taken place in them during use. *(To be concluded)*

### *References*


[1] Sosman: "Pyrometry and the Steel-Maker's Refractories," Journal Amer. Cer. Soc., Vol. 21, pages 37-49 (1938).

[2] Larsen and Schroeder: "Service Conditions of Refractories for Open-Hearth Steel Furnaces," Bull. No. 23 Mining & Metallurgical Investigations. Carnegie Institute of Technology, 1925.

[3] McCaughey: "Contribution of Mineralogy to Ceramic Technology and Research," Journal Amer. Cer. Soc., Vol. 20, pages 31-42 (1937).

*Tapping steel from one of several electric arc furnaces in a large foundry. (Courtesy: Ford Motor Co.)*

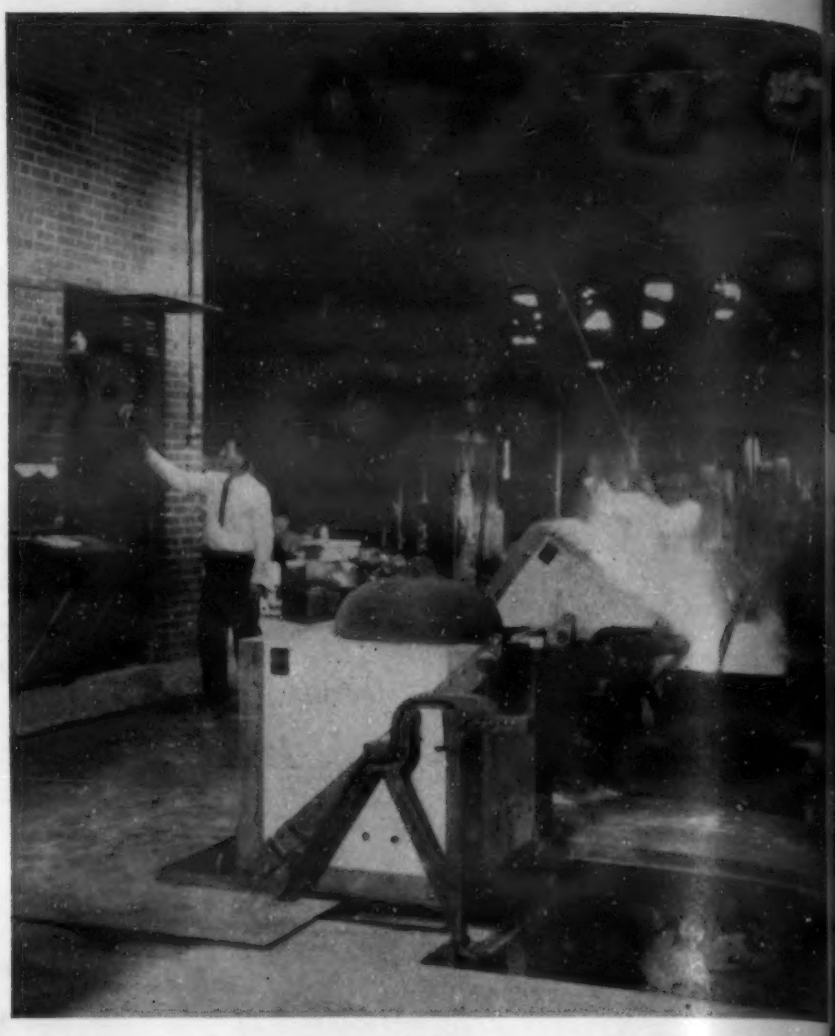
# Steel Foundry Progress in Melting and Heat Treating

BY EDWIN F. CONE

THE STEEL CASTING INDUSTRY, while not the largest branch of American steel operations, is a highly important one. Its total capacity is about 2,000,000 gross tons annually, and its products, by whatever process made and whether plain carbon or alloy, are essential to many undertakings.

In the last 10 to 20 years, this industry has been subject to intense competition—from improved gray iron, particularly alloy; from malleable irons, to some extent; from welded products in place of castings and in other directions. The industry has had to combat these with improved technique in several directions—alloying, melting equipment, heat treatment and so on. To what extent has this been accomplished, and how?

*Pouring copper-silicon steel for cast crankshafts from an electric arc furnace. (Courtesy: Ford Motor Co. of Canada)*



*Steel from one of two Ajax high-frequency furnaces for casting high-alloy castings. (Courtesy: Lebanon Steel Foundry)*

One answer to this, we think, is a knowledge of the strides which the industry has made in recent years in its melting and heat-treating equipment. Periodically the Steel Founders' Society of America issues a directory of steel foundries in the United States and Canada. We have taken the issue for 1939 and analyzed it in considerable detail. This directory, on the authority of the S. F. S. A., "embraces approximately 99 per cent of all the active commercial steel foundries and a very large proportion of the foundries engaged in the production of steel castings for their own use." Some of the results of this analysis are given in the following paragraphs.

## Electric Melting Furnaces

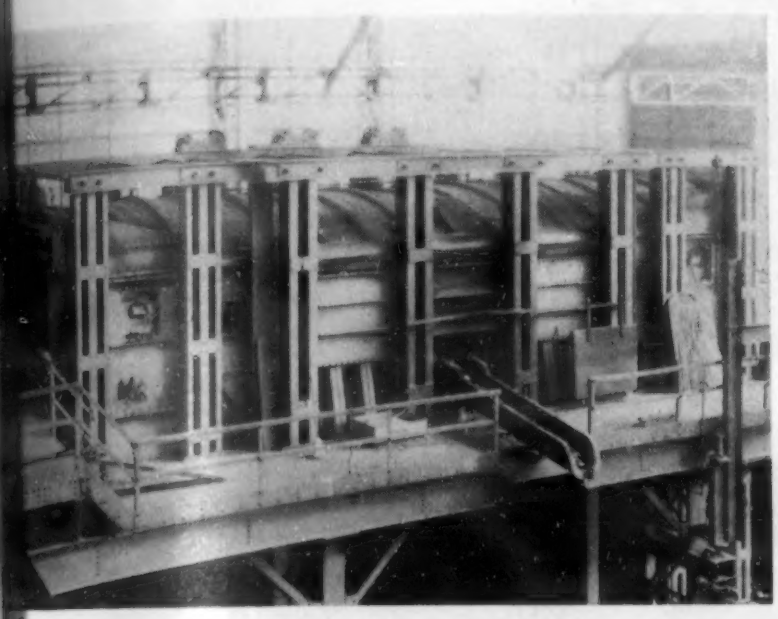
Last year there were 319 electric furnaces of various types in the American steel casting industry, distributed among 167 plants. The tendency in the last 10 years or so has been an increase in furnaces, there having been in 1929, approximately 287 furnaces in 182 plants, according to the S. F. S. A. 1930 directory. Therefore there has been a tendency to concentrate the electric melting capacity in a smaller number of plants.

The electric furnaces operating last year in the industry were the following:

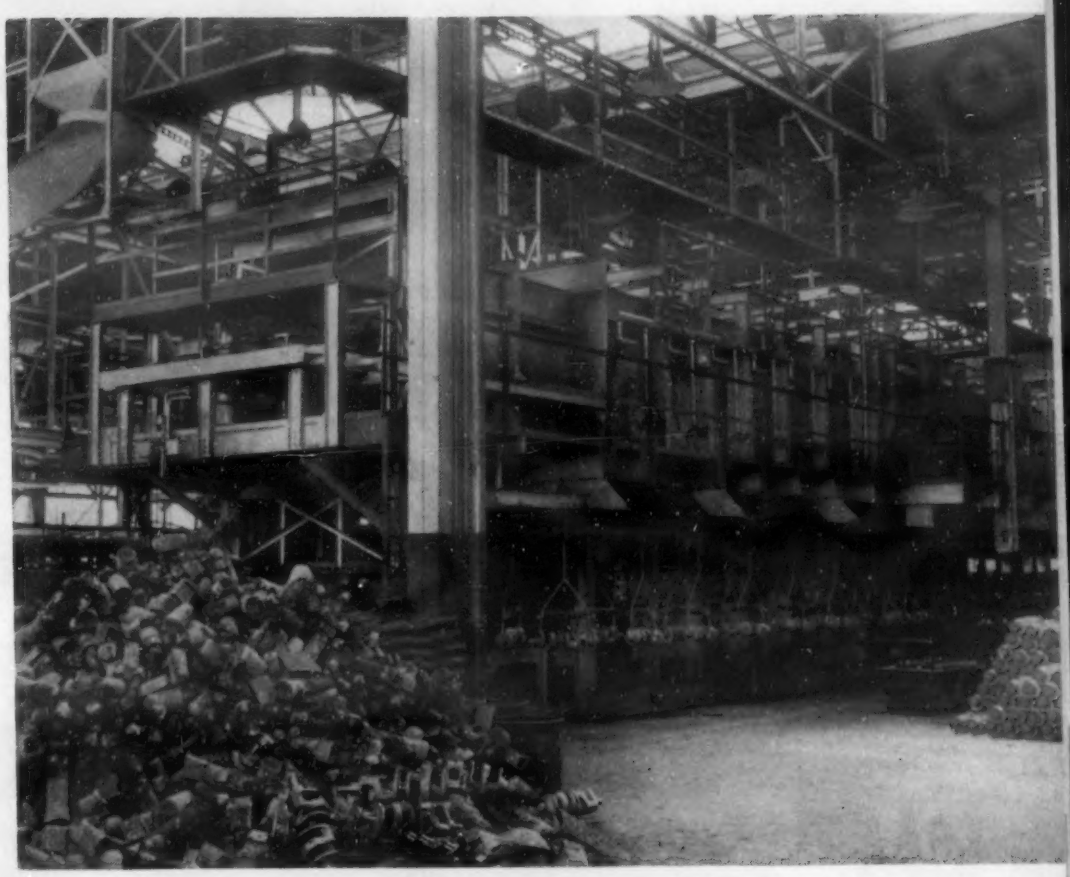
| *Type* | *No.* | *Type* | *No.* |
|---|---|---|---|
| 'Lectromelt | 110 | "Industrial" | 3 |
| Not Designated | 63 | Kay | 3 |
| Heroult | 54 | Rennerfelt | 2 |
| Arnold | 7 | Booth-Hall | 1 |
| Ajax High Frequency | 23 | Booth | 1 |
| Greene | 17 | Rockwell | 1 |
| Swindell | 8 | Girod | 1 |
| "Own Make" | 7 | Gronwall-Dixon | 1 |
| Detroit | 6 | Ludlum | 1 |
| Snyder | 5 | "Special Built" | 1 |
| Graves-Etchells | 3 | Experimental | 1 |
| | | Total | 319 |

From this tabulation the 'Lectromelt or Pittsburgh (Moore) furnace leads with the Heroult type second. Some of the "Not Designated" furnaces (63) are either Moore or Heroult or some other type. The total of 54 Heroult should be augmented by the 7 Arnold which are a modified Heroult type. The

*(Left): A car-bottom annealing furnace for steel castings. (Courtesy: Steel Founders' Society of America)*



*Typical open-hearth furnace in a large American steel foundry, the General Steel Castings Corp. (Courtesy: Steel Founders' Society of America)*



*A double deck heat-treating furnace for cast steel crankshafts and other products. (Courtesy: Ford Motor Co. of Canada)*

largest unit in use is 7 tons.

The 23 Ajax high frequency units are significant of the increase in use of this kind of melting. In the 1930 Directory, only 7 of these furnaces are listed. This means more than a threefold gain since 1929. There have been several new installations since the 1939 Directory was published, notably those in the foundry of the Crane Co. at Chicago. Since the foundry of the Babcock & Wilcox Co. at Barberton, Ohio, is not included in the 1939 Directory, which is probably the largest one using Ajax furnaces, the total now in use in the United States in steel foundries is approximately 35.

The Greene furnace, largely in use in the West, is holding its own at 17 installations as compared with about 15 in 1929.

Cognizance should also be taken of the electric furnace equipment in the large foundry of the Ford Motor Co., which is not included in the 1939 Directory. In that foundry there are several electric furnaces including the Moore, Heroult and Swindell, some of the latter having been added recently for melting metal for the Ford crankshafts and the centrifugally cast gear blanks, all classed as steel castings.

The progress which has been made in the use of the electric furnace for steel castings can be partly measured by referring to the situation about 20 yrs. ago. As one of the editors of *The Iron Age*, the writer published for a number of years an annual survey of the electric furnace steel industry. In one of these, published Jan. 1, 1920, page 75, there were 323 electric furnaces in the entire industry n 1919 including those making ingots and castings. Therefore at the present time there are as many or more electric furnaces in the steel casting industry than there were in the entire steel industry 20 years ago.

## Converter and Crucible Melting

Some years ago the side-blow converter was extensively used as a melting medium in small steel foundries. In 1939 there were 28 converters in 19 plants—a decided decrease from the 45 in 32 plants in 1929. This has been due largely to the sub-

stitution of the electric furnace for the converter or to the abandonment of some converter foundries.

Crucible steel has never been extensively used for steel castings. Rather unexpectedly, however, we find that between 1929 and 1939 there has been little change—17 crucible furnaces in 8 plants 10 yrs. ago as compared with 21 in 7 plants in 1939. The capacity is only about 2,000 gross tons each year.

## Open-Hearth Steel

By far the great bulk of steel castings is poured from open-hearth furnaces—this has always been the case. The 1939 S. F. S. A. Directory shows that there were then 182 furnaces in 61 plants. The capacity of these furnaces is approximately 1,400,000 tons yearly compared with an annual electric furnace capacity of about 500,000 tons. The size of the open-hearth furnaces in use, ranges from 6-ton to 175 tons each. It may also be added that most of the plain carbon castings are made from open-hearth steel, and that the expansion in electric furnaces in recent years is due to a greater demand for alloy castings, particularly those of high alloy content.

Viewed from another angle the following classification or breakdown of the 1939 status is interesting:

| | | |
|---|---|---|
| Open-Hearth | 182 | furnaces in 61 plants |
| Electric | 319 | furnaces in 167 plants |
| Converters | 28 | units in 19 plants |
| Crucible furnaces | 31 | units in 7 plants |
| Electric and Open-Hearth | 23 | plants |
| Electric and Converter | 3 | plants |
| Electric and Crucible | 2 | plants |

## Heat Treating

Even greater progress has been made in the last 10 to 20 years in heat-treating practice and equipment in American steel foundries than in melting. This has been the result of a better fundamental knowledge of the function of heat treatment and of a desire to produce a better product. The coming into the picture of alloy castings which require accurate and varied heat treatment has also been a factor.

In the early days of the steel foundry industry, the writer remembers definitely that the annealing of ordinary carbon steel castings was little understood—in most cases they were superficially annealed. It was taken for granted that if, after heating in an annealer or coal-fired oven, the castings came out with a reddish color, they were annealed. No attention was paid to the fracture which in many cases was still highly crystalline. Such castings were accepted as annealed by both Government and railroad inspectors.

Today the situation is vastly different—castings must be heated to definite temperatures and for definite periods, depending on the composition, followed by various conditions of cooling. It is now the practice in certain cases to even quench or quench and draw castings—a practice which 20 to 25 years ago was looked upon as disastrous.

The 1939 Directory of the S. F. S. A. gives in most cases a listing of the heat-treating equipment. These listings have been analyzed in some detail with the following general results.

Not all of the 226 companies included in the S. F. S. A. 1939 Directory reported their heat-treating equipment in detail—fuel used and type of furnace. Analyzing those that did report the following general summary is possible so far as fuels used and the number of furnaces:

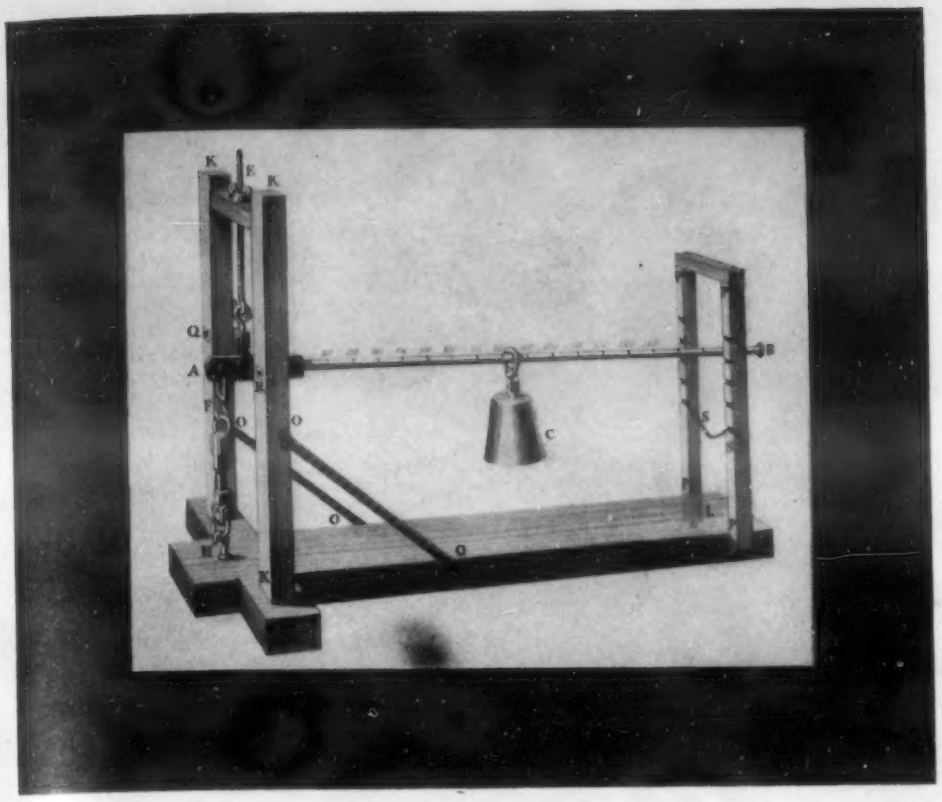
| *Fuel* | *In Electric Foundries* | *In Open-Hearth and Others* |
|---|---|---|
| Oil | 196 | 79 |
| Gas | 138 | 56 |
| Electricity | 32 | .. |
| Natural Gas | 14 | 24 |
| Coal | 7 | 11 |
| Wood | .. | 1 |

## Types of Heat-Treating Furnaces

The types of furnaces used embrace almost the entire list with the car type predominating at 250 in all the foundries reporting. Next to the car type ranks the pit type, the latter predominating naturally in the open-hearth plants (43 to 13). Besides these, others include the box, pusher, car bottom, hearth, floor, batch, truck, double chamber, semi-muffle, chain type and so on. The smallest furnace is the ½-ton box type, fired with gas, and the largest is a 400-ton oil-fired pit unit. Besides these, and including many sizes, is a 50-ton truck type, oil-fired, and a 250-ton pit type fired with natural gas.

In many cases the names of the company supplying the furnaces are given. A partial list of those follows: Surface Combustion, 14; Mahr, 12; Hevi-Duty, 7; Stuart, 7; Ryan, 6; Whiting, 4; Salem, 4; Swindell, 3; Gas Machinery, 3; Stevens, 3; Hagan, 2; Lindberg, 2; Atlas, 2; Industrial, 2; with one or more each for National Supply, Strong-Carlisle, Rotary, Enterprise, Philadelphia Drying, Tate-Jones, Holcroft, General Electric, etc.

This analysis of the status of the American steel foundry industry answers in part the question raised early in this discussion—the severe competition of the last decade or so has been countered with an increase in electric melting equipment, particularly for alloy castings; in the latest types of heat-treating furnaces; in improved melting and heat-treating technique and in improving in every way possible the quality of the product.



*A far cry from the present-day testing machines is the one built by Pieter van Musschenbroeck, a Leyden professor, in 1729. It consists of a framework on which an ordinary steelyard was mounted. A movable weight provided the loading means.*

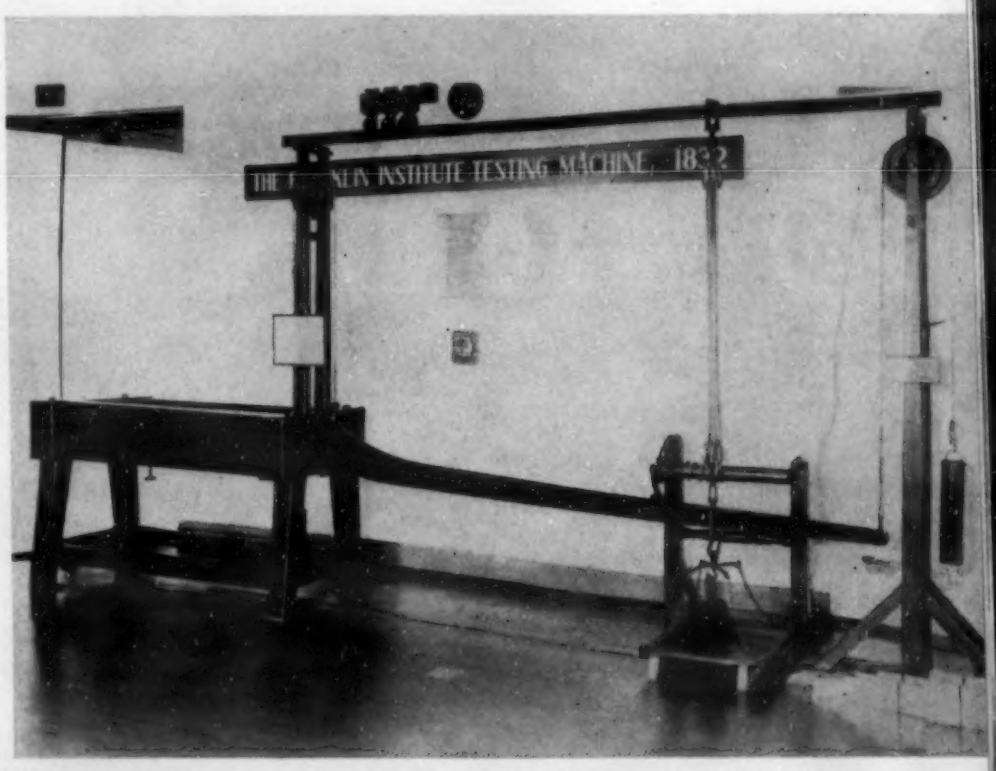
# Testing Machines --- Old and Modern

AT THE RESEARCH LABORATORIES of the Aluminum Co. of America, New Kensington, Pa. a demonstration of the new Templin precision metal working machine was made before an assemblage of industrial officials, representatives of the trade and technical press, and others. It is described as a "new 3-story hydraulic monster, powerful enough to flatten a locomotive boiler like a 5-ton truck rolling over a tobacco tin, yet so 'gentle' that it can crack a watch crystal without harming the works."

The machine, one of the largest in the world, is named after R. L. Templin, chief engineer of tests of the Aluminum Co. of America. It is capable of exerting a force of 3,000,000 lbs. in compression (pushing) and 1,000,000 lbs. in tension (pulling). While it is not the largest of its kind in the world, it is rated as the "most powerful" because it can exert these terrific forces at speeds up to 36 in. a minute—faster than any other testing device—and "power is defined as force times speed." The machine was built by the Baldwin-Southwark Corp. of Philadelphia.

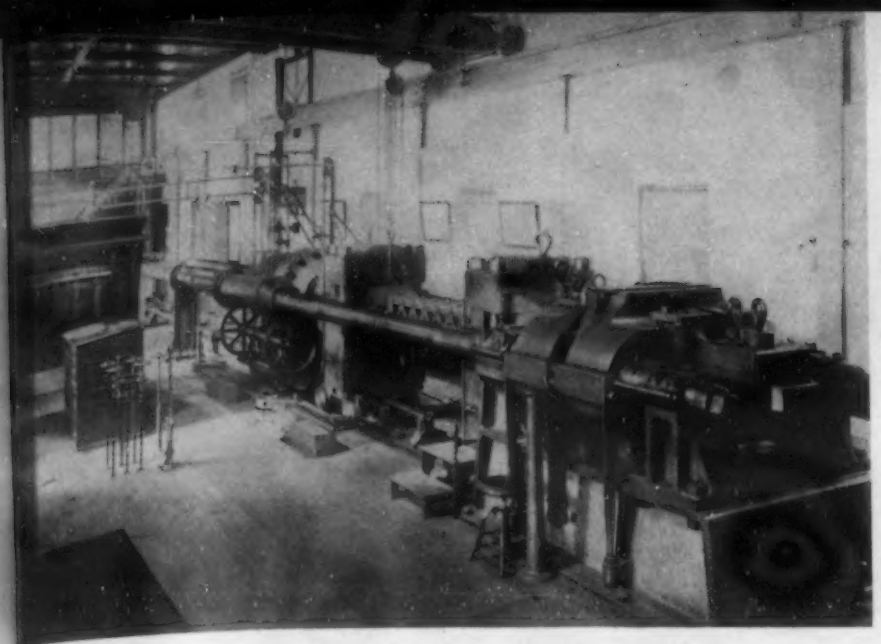
While the Templin machine can make tests to destruction, it can also be operated as an extrusion, forging, or forming press. It will be used for research in these various capacities.

A series of pictures, furnished by the Aluminum company, are presented on this and the following pages showing to some extent the evolution of this large testing machine from some of the early testing apparatus.

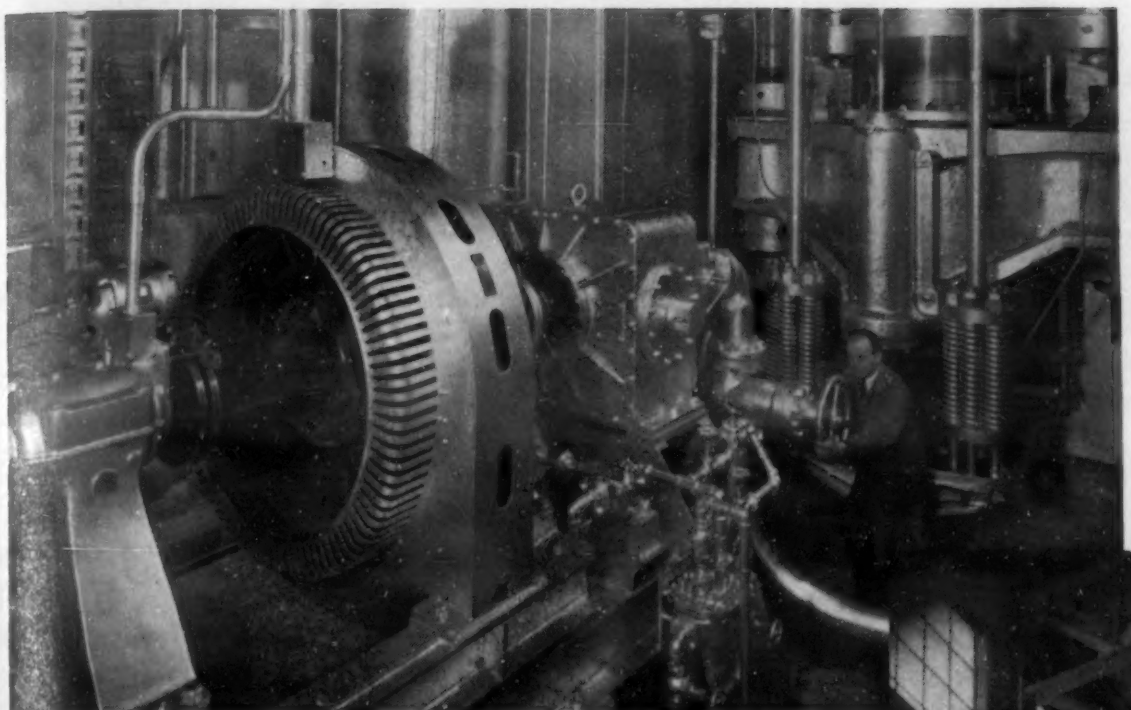


*The first testing machine ever built in America of which there is a record was developed by the Franklin Institute in 1832. It may be seen in the museum of the institute today, intact and in serviceable condition—although much too small for the requirements of modern scientific exploration.*

*One of American industry's most Gargantuan tools for research—the Templin precision metal working machine as seen from a crane above. It has a capacity of 3,000,000 lbs. in compression (pushing) and 1,000,000 lbs. in tension (pulling). The ability to move the head of the machine at speeds as high as 36 in. per min. under full load makes this the most powerful machine of its kind in the world. It is 25 ft. high from floor to top, and 15 ft. below the floor.*

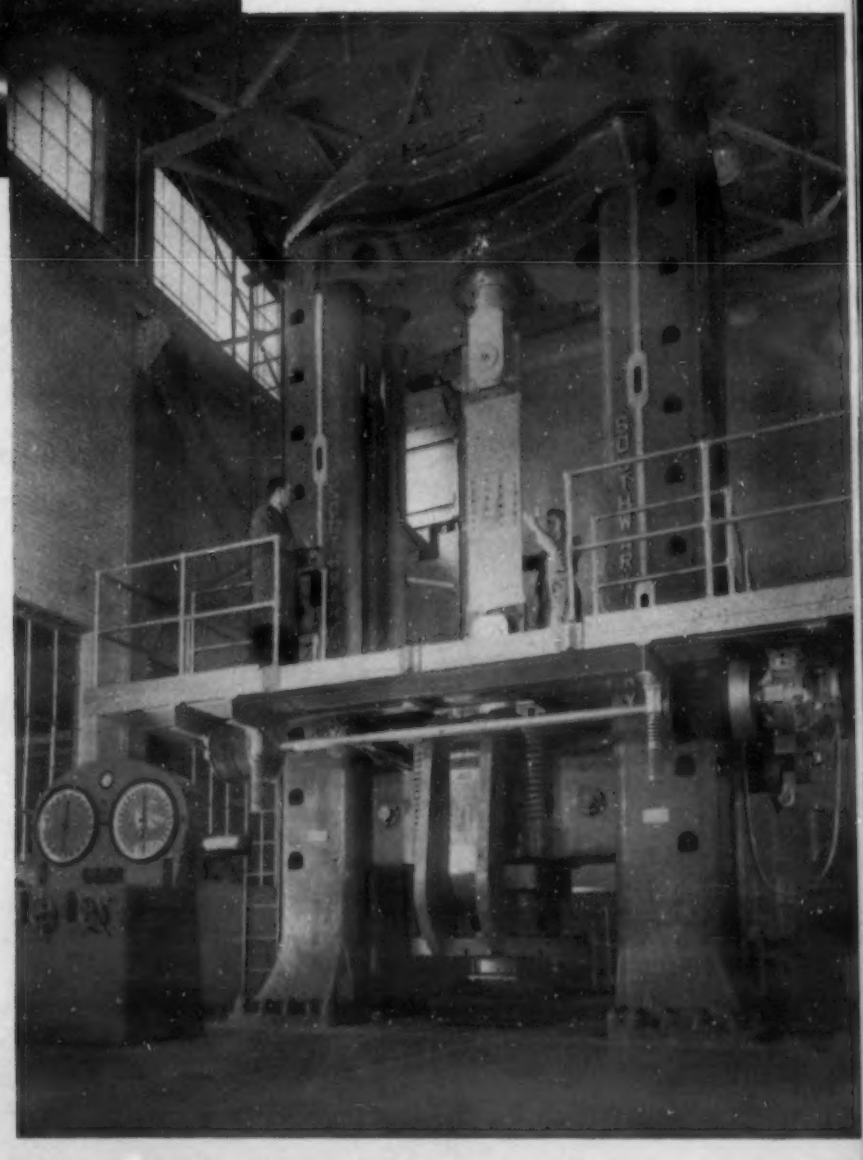


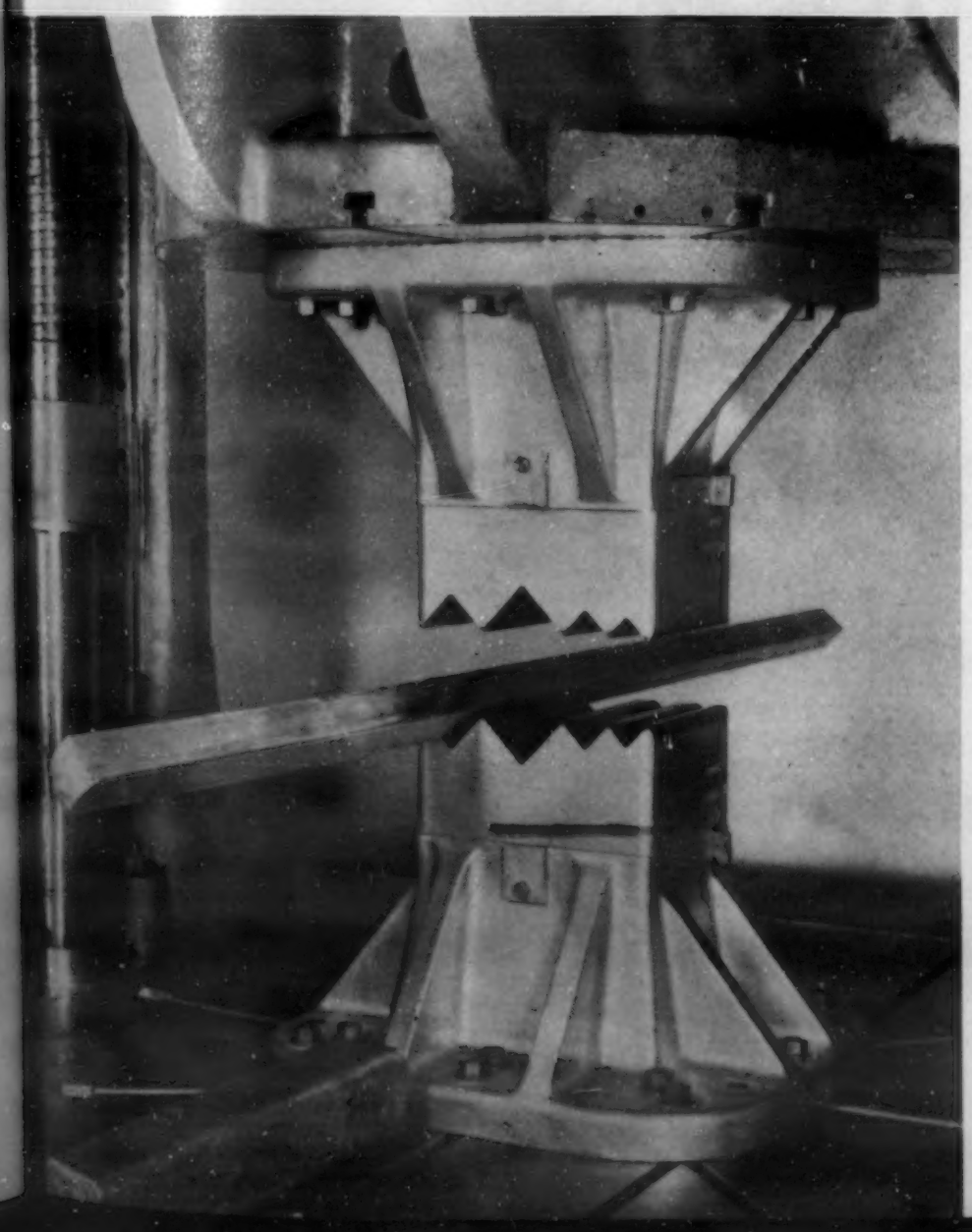
*The famous "United States testing machine," built for the Watertown Arsenal, near Boston, in 1879. It is able to exert a force of 1,000,000 lbs. in compression, 800,000 lbs. in tension, and for the past 60 years has been noted as one of the largest and most precise testing machines in the world.*



*Left: The operating machinery of the Templin precision metal working machine is located below the floor. The oil pump and the 300-hp. motor furnish power to the large machine through the hydraulic cylinder at the right.*

*Below: Testing engineers are dwarfed by the size of the new Templin precision metal working machine. The elevator around the machine has been raised so that the man at the right can take a reading on the large aluminum riveted joint which is to be pulled apart.*





*Left: Press forging an aluminum ingot in the Templin precision metal working machine. This machine, which can exert pressures up to 3,000,000 lbs., is so sensitive that it can also break a watch crystal without harming the works, or crack an egg without spilling the contents.*

# Effect of Phosphorus in 5 P

**by H. D. NEWELL and Z. E. OLZAK**

*Chief Metallurgist & Metallurgist, Respectively, Babcock & Wilcox Tube Co., Beaver Falls, Pa.*

*This article is based on one of the internal reports of the Babcock & Wilcox Tube Co. and is of decided interest. It discusses the results of a research to determine the effect of phosphorus additions to the 4 to 6 per cent Cr, ½ per cent Mo steels.*

*The report shows that the high temperature strength-producing effects of molybdenum and phosphorus are compatible and more or less additive, in line with work that has been done in other laboratories. The high temperature effect of phosphorus has been overlooked, and is still overlooked, by most people and the evidence in this article is very much worthwhile.—The Editors.*

THE USE OF PHOSPHORUS as an alloying element is common in several of the commercial high yield strength, low alloy steels. Its behavior in such use has recently been summarized by Lorig and Krause.[1] Cross and Krause[2] found that phosphorus increased the high temperature strength of Cr-Mo steels, the compositions studied being 1 Cr, 0.2 Mo; 1 Cr, ½ Mo; and 2.4 Cr, 0.2 Mo.

I. Harter, vice president, Babcock & Wilcox Tube Co., suggested that a brief study be made to find whether the strengthening effect of P extends to the 5 Cr, ½ Mo type, and what advantages or disadvantages such an addition would show in view of the service to which this type of steel is put, namely oil refinery piping and still tubes and steam super heater tubes.

## Composition of the Heats

Accordingly, a series of steels was made up with the compositions shown in Table I, in 60 lb. 4 by 4 by 13 in. (after cropping the hot top) ingots from high frequency furnace melts.

Phosphorus additions were made by means of electric furnace ferro-phosphorus containing 25 per cent phosphorus. The ingots were reduced to 1-1/16-in. round under a 500-lb. hammer. All forging was done at 2100 to 2150 deg. F. No difficulty was experienced in forging any of these ingots—in fact, the higher phosphorus ingots seemed to reduce to a greater extent with each blow of the hammer than the lower phosphorus material.

All material was annealed by heating to 1575 deg. F. for 1 hr. and cooling at the rate of 20 deg. F. per hr. to 1300 deg. F., from which point the material was furnace cooled.

## Etch Test—As Cast

A disc ¾ in. in thickness was cut from the top of each ingot underneath the hot top. The discs were machined, polished and etched in hot 1:1 hydrochloric acid. Segregation and "pipe" increases gradually as phosphorus is added with "pipe" being especially evident in the ingot containing the highest amount of phosphorus. This condition is undoubtedly due to the strongly deoxidizing effect of phosphorus. Fig. 1 shows the cross-section of each ingot after etching.

## Room Temperature Properties

Results of the room temperature tests are shown in Fig. 2. Proportional limit was taken by means of an Olsen extensometer sensitive to 0.000066 in.

*TABLE 1—Analysis of High Frequency Furnace Melts*

| Heat No. | 935 | 934 | 930 * | 932 | 933 | 936 |
|---|---|---|---|---|---|---|
| Carbon | 0.098 | 0.104 | 0.108 | 0.092 | 0.092 | 0.12 |
| Manganese | 0.36 | 0.42 | 0.37 | 0.38 | 0.35 | 0.45 |
| Silicon | 0.356 | 0.334 | 0.28 | 0.40 | 0.30 | 0.418 |
| Chromium | 5.07 | 4.99 | 4.88 | 5.01 | 4.79 | 5.25 |
| Molybdenum | 0.58 | 0.54 | 0.54 | 0.51 | 0.48 | 0.58 |
| Phosphorus | 0.020 | 0.116 | 0.094 | 0.202 | 0.46 | 1.00 |

*** Heat No. 930 is practically of the same analysis as No. 934, the difference being that this particular heat was wild. The first heat, melted in a new crucible, generally turns out wild in spite of the fact that it is melted and deoxidized in the usual manner. Heat No. 930 is a melt of this nature and was incorporated in this investigation for comparative purposes only.**

BRINELL HARDNESS:

| Heat No. | Phos. | As Cast | As Forged | Annealed |
|---|---|---|---|---|
| 935 | 0.020 | 400 | 363 | 124 |
| 934 | 0.116 | 368 | 363 | 143 |
| 930 * | 0.094 | 380 | 388 | 137 |
| 932 | 0.202 | 302 | 354 | 156 |
| 933 | 0.46 | 255 | 302 | 179 |
| 936 | 1.00 | 266 | 333 | 189 |

* Wild heat.

# 5 Per Cent Cr, 0.50 Mo Steel

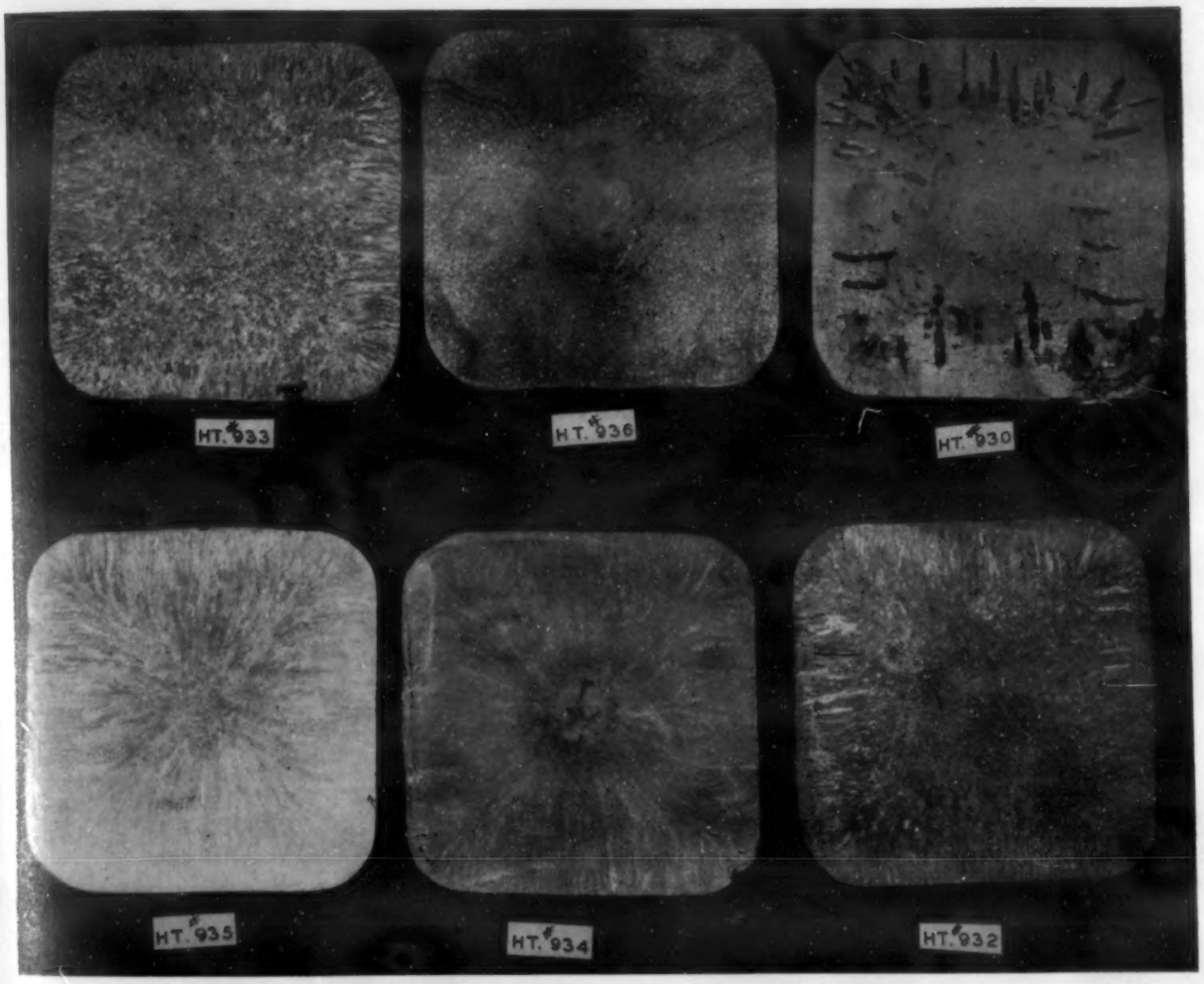



*Fig. 1. Cross-section of each ingot after etching.*

Readings were taken with each increase of 200-lb. load. The tensile tests at room temperature show good physical properties up to and including the 0.46 per cent phosphorus steel. The rise in proportional limit, yield, and tensile strength is marked as the phosphorus is increased. The 1.00 per cent phosphorus material shows a drop in yield, heat No. 936, with tensile strength remaining at the high point.

There is a slight decline in ductility starting with the 0.202 per cent phosphorus steel which increases correspondingly until the 1.00 per cent phosphorus steel shows a brittle fracture with very little elongation or reduction in area.

## Short-Time High Temperature Properties

Short-time high temperature tests were made on each of the different materials and properties determined through the range 900 to 1300 deg. F. Results of these tests are shown in Fig. 3. The tests indicate that increased strength, attributed to phosphorus, is also noticeable at elevated temperatures.

## Impact and Hardenability Tests

Charpy impact tests were made on standard 0.394 in. square key-hole notched specimens. Results of

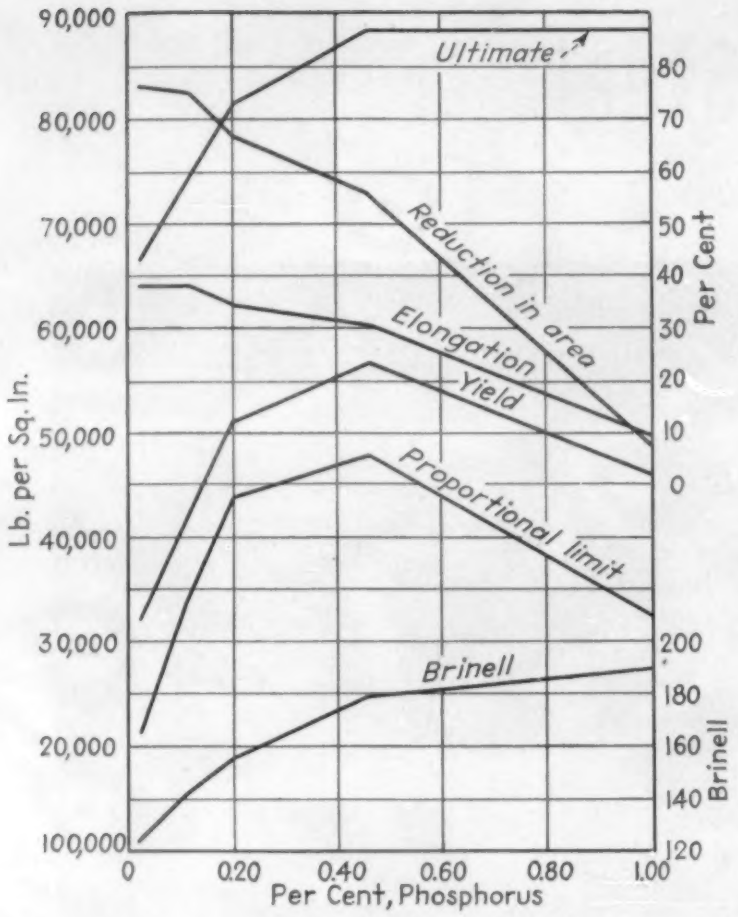



*Fig. 2. Results of the room temperature tests.*

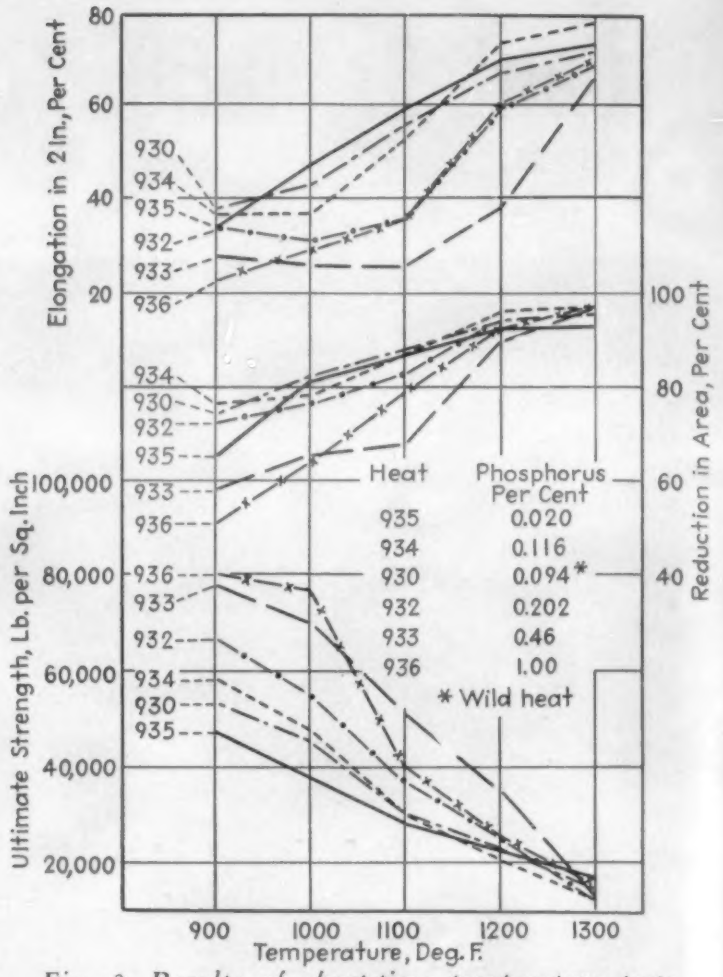



*Fig. 3. Results of short-time temperature tests.*

these tests are given in Table 2.

Hardenability was studied on specimens 1-1/16 in. in diam. by 3/8 in. long, air cooled or water quenched at 100 deg. intervals from 1300 to 2300 deg. The data are given in Table 3.

## Atmospheric Corrosion Test

Samples 3/4 in. in dia. by 2 in. long were polished roughly on an emery belt grinder and suspended on glass rods out in the weather for a period of 1200 hrs. At the end of this time all the samples were covered with a heavy coating of rust. The resistance to atmospheric corrosion of each individual sample could not be judged accurately by

*TABLE 2—Charpy Impact Tests at Room Temperature of 5 Per Cent Cr, 0.50 Per Cent Mo with Phos.*

| Heat | Phos. | Ft. Lbs. | Average |
|---|---|---|---|
| 935 | 0.020 | 50—48—49 | 49 |
| 934 | 0.116 | 41—41—42 | 41 |
| 930 * | 0.094 | 37—37—38 | 37 |
| 932 | 0.202 | 34—35—36 | 35 |
| 933 | 0.46 | 2— 2— 2 | 2 |
| 936 | 1.00 | 2— 2— 2 | 2 |

* Wild heat.

*TABLE 3.—Hardenability Cycle of 5 Per Cent Cr, 0.50 Per Cent Mo with Phos.*

| | Air Cooled | | | | | | Water Quenched | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Brinell Hardness | | | | | | Brinell Hardness | | | | | |
| | Heat Numbers | | | | | | Heat Numbers | | | | | |
| Temp. °F. | 935 | 934 | 930 | 932 | 933 | 936 | 935 | 934 | 930 | 932 | 933 | 936 |
| 1300 | 125 | 140 | 135 | 156 | 170 | 187 | 127 | 143 | 141 | 156 | 177 | 185 |
| 1400 | 126 | 143 | 137 | 157 | 179 | 195 | 131 | 144 | 141 | 163 | 179 | 197 |
| 1500 | 135 | 143 | 137 | 157 | 184 | 213 | 137 | 154 | 149 | 164 | 185 | 215 |
| 1600 | 341 | 255 | 272 | 255 | 255 | 266 | *363* | 325 | 359 | 266 | 269 | 288 |
| 1700 | 359 | 341 | 359 | 255 | 255 | 295 | 363 | *363* | *363* | 359 | 302 | 341 |
| 1800 | 363 | 359 | 359 | 341 | 285 | 321 | 363 | 363 | 363 | *363* | 341 | *363* |
| 1900 | 359 | 341 | 359 | 363 | 285 | 321 | 363 | 363 | 363 | 363 | *363* | 341 |
| 2000 | 337 | 341 | 341 | 363 | 302 | 341 | 363 | 359 | 345 | 363 | 341 | 341 |
| 2100 | 341 | 341 | 363 | 363 | 302 | 341 | 341 | 359 | 363 | 363 | 341 | 341 |
| 2200 | 341 | 341 | 345 | 363 | 285 | 321 | 341 | 363 | 363 | 363 | 325 | 341 |
| 2300 | 341 | 341 | 341 | 363 | 288 | 321 | 341 | 359 | 354 | 359 | 302 | 298 |

It may be noted that phosphorus reduces hardenability in air somewhat with slight effect on hardenability on water quenching. Phosphorus raises the $A_3$ transformation and therefore raises the temperature at which full hardening occurs.

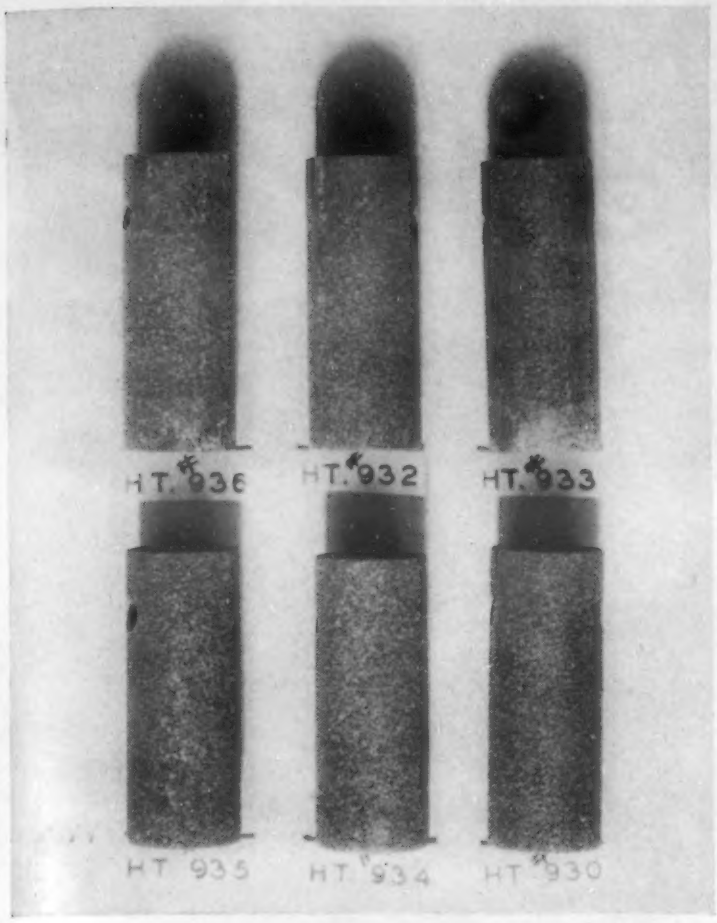


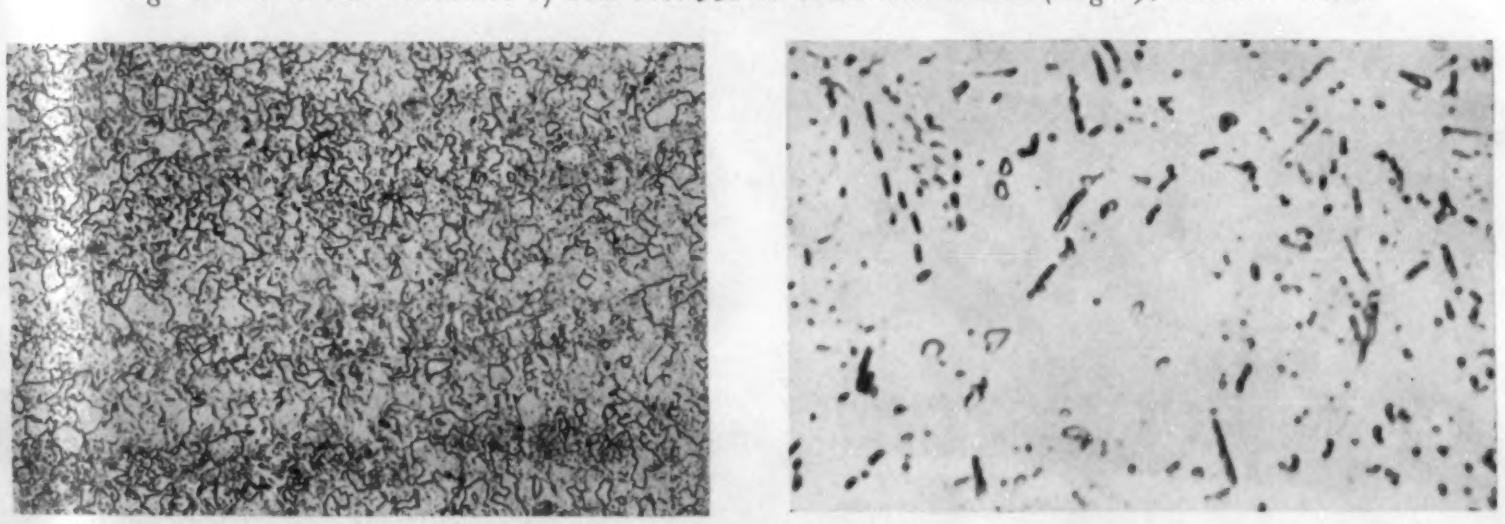

*Fig. 4. Photographs of the samples tested.*

examination although the higher phosphorus samples, Heats No. 932, 933, and 936 to all appearances had withstood the test better than the lower phosphorus samples, Heats No. 935, 934, and 930. The first named samples had a hard, more adhering oxide rust coating that was somewhat smoother in appearance. On the other hand, the lower phosphorus samples had a loose coating with a surface that appeared somewhat rougher. This may be taken as an indication that the higher phosphorus material, that is, material with 0.20 per cent or more phosphorus, is slightly superior insofar as atmospheric corrosion is concerned. Fig. 4 is a photograph showing the samples tested. The period of exposure was short, for this type of testing. In other phosphorus-containing steels, the beneficial effect of phosphorus has been found to become more evident as the exposure time increases.

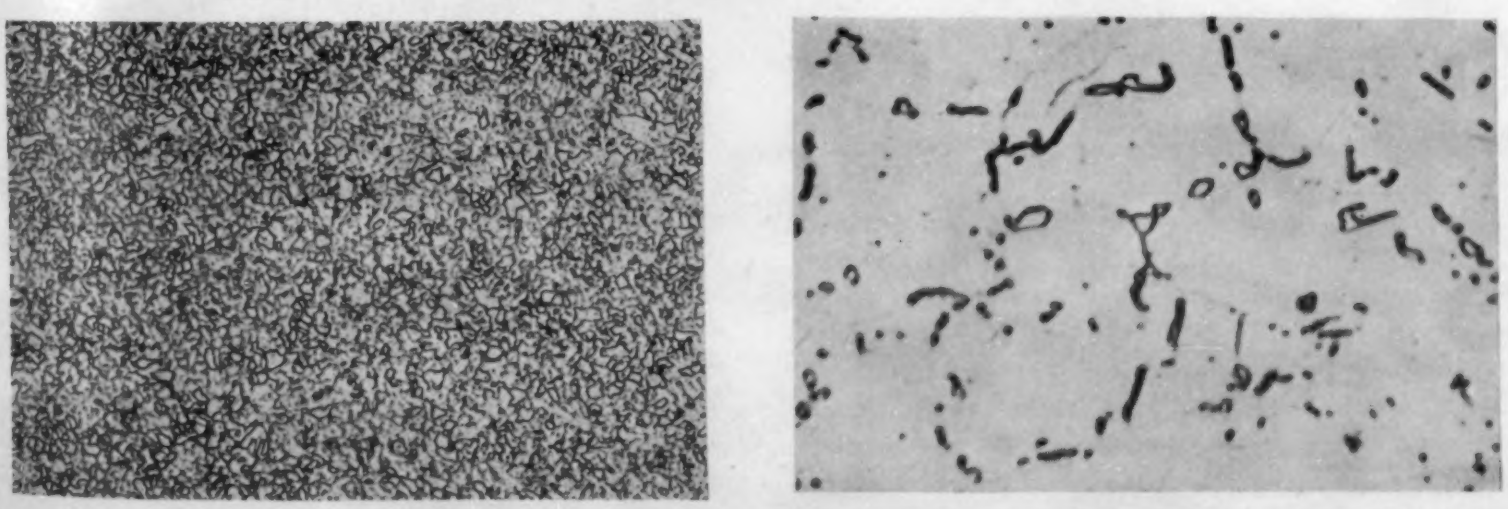
## Weld Hardening Test

A piece of bar representing each heat was annealed and a single bead of weld metal laid on by arc welding using Fleet Weld coated soft steel rod. The Rockwell hardness and Brinell equivalent of

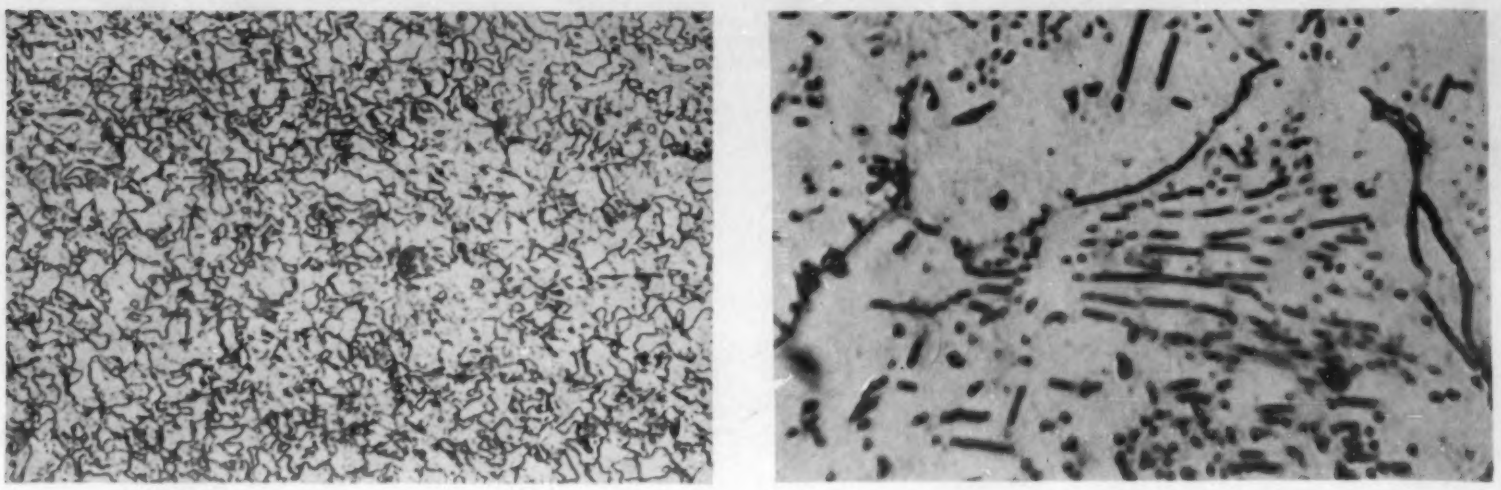
*Figs. 5 and 6. Microstructure of heat No. 935 at 100X and 2000X (Right). Etchant: Nital.*

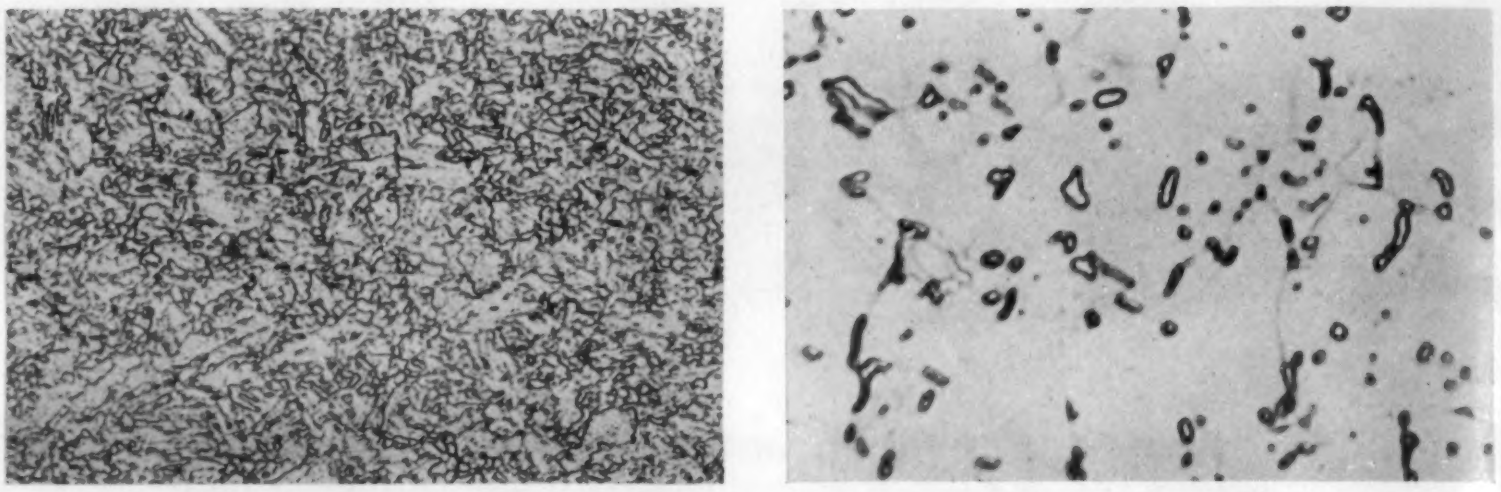


*Figs. 7 and 8. Microstructure of heat No. 934 at 100x and 2000x (Right). Etchant: Nital.*



*Figs. 9 and 10. Microstructure of heat No. 930 at 100X and 2000X (Right). Etchant: Nital.*





*Figs. 11 and 12. Microstructure of heat No. 932 at 100X and 2000X (Right). Etchant: Nital.*

the weld metal and heat affected regions of the material in the "as welded" condition are given below:

| Heat | Weld Metal | | Weld Affected Zone | |
|---|---|---|---|---|
| | Rockwell | Brinell | Rockwell | Brinell |
| 935 ..... | B-100 | 242 | C-32 | 396 |
| 934 ..... | B-96 | 216 | C-35 | 322 |
| 930 ..... | B-98 | 228 | C-36 | 331 |
| 932 ..... | B-97 | 222 | C-37 | 340 |
| 933 ..... | B-95 | 210 | C-32 | 296 |
| 936 ..... | B-98 | 228 | C-34 | 313 |

It can be seen from the foregoing that apparently phosphorus, in any amount up to 1 per cent, does not substantially reduce weld hardening or 5 per cent Cr, 0.50 per cent Mo steel to below that of a low phosphorus steel containing the same carbon content.

## Metallographic Examination

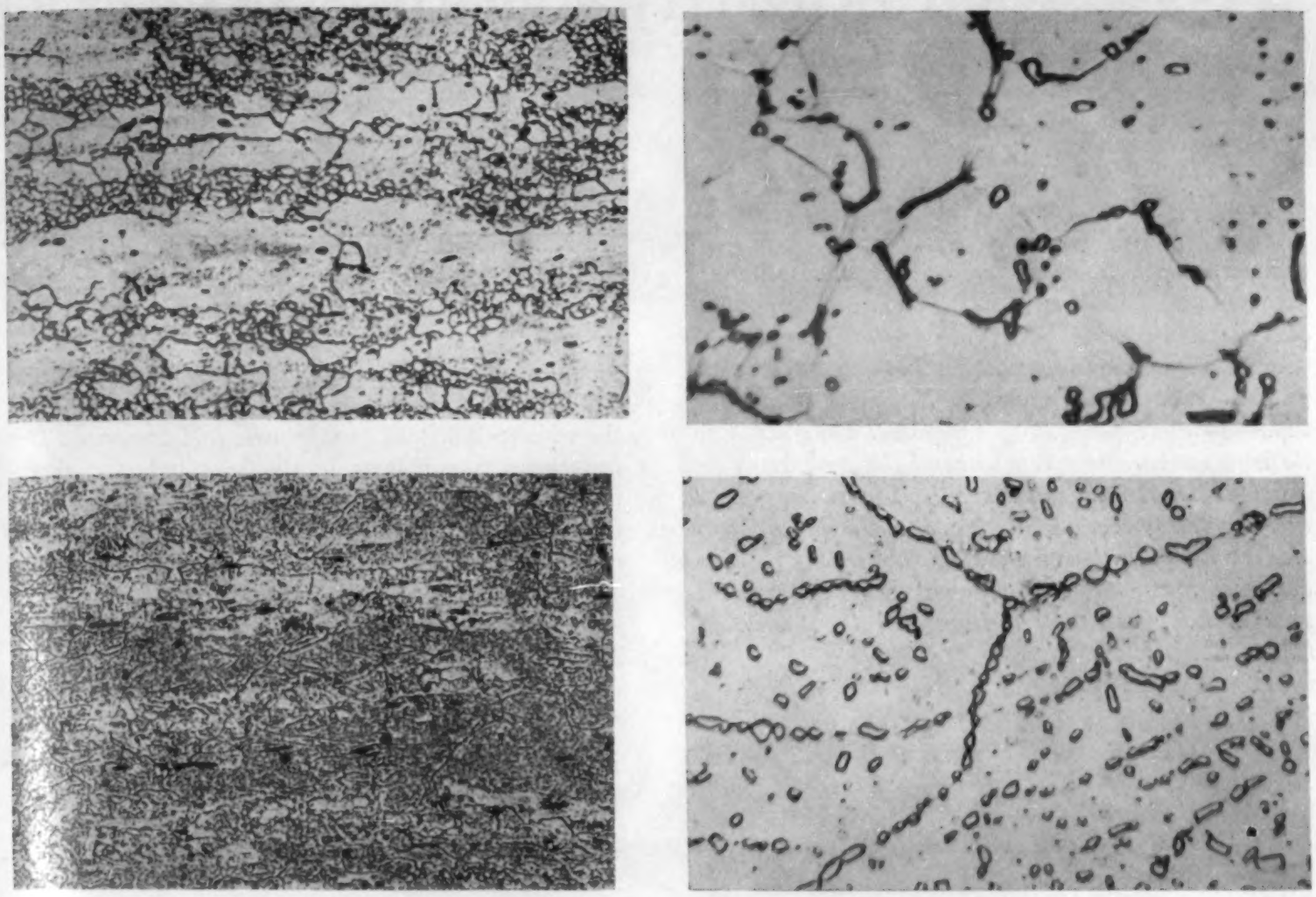
The microstructures of all the heats, in the annealed condition, are shown in Figs. 5 to 16 inclusive both at 100 and 2000 dia. There is little difference in the microstructure of the lower phosphorus materials. The greatest change in structure is evident in the 0.46 per cent and 1.00 per cent P steels. Phosphorus in these two heats tends towards larger grain size. This is reflected in tensile and impact tests on these materials. There is evidence of more carbon out of solution in the 1.00 per cent P material which may partially explain the drop in yield of this material as compared with the other heats. The two higher phosphorus steels contained free ferrite, indicating that they are approaching the alpha-delta type, i. e., lacking complete gamma transformation.

## Discussion

It is evident from results obtained in this investigation that phosphorus, within definite limits, has a beneficial effect on 5 per cent chromium, 0.50 per cent molybdenum steel, inasmuch as it increases hardness, raises proportional limit, yield and tensile strength without seriously affecting ductility. This increased strength, which is attributed to alloying with phosphorus, holds at elevated temperatures. Of interest in this respect is the fact that short-time tensile tests show the yield point to be higher at 900 deg. F., than at room temperature in all the steels containing phosphorus starting with 0.094 per cent (Heat No. 930). Heat No. 935 which contains little phosphorus (0.020 per cent) showed a lower yield at 900 deg. F. than at room temperature. as might be expected.

Impact tests show good resistance to impact on material containing phosphorus up to 0.202 per cent. While there is a slight decline in impact resistance with increased phosphorus, this decline is not serious until the percentage of phosphorus is raised above

*Figs. 13 and 14. Microstructure of heat No. 933 at 100X and 2000X (Right). Etchant: Nital.*



*Figs. 15 and 16. Microstructure of heat No. 936 at 100X and 2000X (Right). Etchant: Nital.*

0.20 per cent. At 0.46 per cent and above, the resistance to impact is practically zero (actually 2 ft. lbs.). The indications are that the limit for alloying of phosphorus with this type of steel would be about 0.25 per cent P. This steel with phosphorus in excess of this amount would be of no use under service conditions where the material is intermittently used at elevated temperatures and is liable to be subjected to shock during shutdowns.

It must be concluded, from weld tests made on all the material at hand, that phosphorus does not materially decrease weld hardening of 5 per cent Cr, 0.50 per cent Mo steel, although in the "as cast" condition, hardness decreases with added phosphorus to a certain extent.

It may be worthy of note that the ingot from the wild heat No. 930, containing many, though clean, blowholes, is scarcely distinguishable in properties from the sound melt No. 934 of practically the same composition. This might be taken as an indication of good weldability, which, indeed, one expects at such a phosphorus level.

## Conclusions

Up to at least 0.20 per cent P, the addition of P to a 0.10 C, 5 Cr, 0.5 Mo steel raises both room temperature and elevated temperature yield and ultimate strength, with little loss in ductility, and, within that range of phosphorus, with the retention of satisfactory toughness in the impact test. If users of the material were educated to its advantages in this steel when used in proper amount, as they have been educated in connection with the constructional low alloy steels that have been developed in recent years; a phosphorus addition might be utilized to enhance the high temperature properties at lower cost than by increasing the content of the other alloying elements in the steel.

The useful limit of phosphorus in this steel appears to lie at much the same level as in other low carbon steels, that is, the sum of C + P should not materially exceed 0.30 per cent and, in order to allow for possible segregation in large ingots, one normally works within the limit of C + P = 0.25 per cent.

### *References*


[1] C. H. Lorig and D. E. Krause. "Phosphorus in Steel." *Iron Age*, Vol. 144, Oct. 19, 1939, pp. 33-37, 88; Oct. 26, pp. 28-31.

[2] H. C. Cross and D. E. Krause. "Phosphorus as an Alloying Element in Steels for use at Elevated Temperatures." *Metals and Alloys*, Vol. 8, Feb. 1937, pp. 53-58.

# The Rolling and Extruding of Le

*The applications of lead sheet and pipe in the manufacture and processing of chemicals, and particularly sulphuric acid, are many, and generally well-known. That these applications depend for their success on uniform and high corrosion resistance of the lead is obvious, but it has not always been so obvious that such factors as the design and the capacity of the fabricating equipment have much to do with the corrosion resistance of the product. This article is a description of a new lead-fabricating plant in New Jersey that was designed and is being operated on the basis that there is a demonstrable relation between the metallurgical engineering equipment used and the corrosion resistance of the fabricated lead.—The Editors.*

TO GIVE THE BEST SERVICE in their most important field of application—the chemical manufacturing industry—lead sheet and lead pipe must be something more than "just lead" rolled flat or pushed through a die. The combination of corrosion resistance and creep strength necessary for long and fool-proof service cannot be consistently attained if composition, internal mechanical structure and dimensions are not right—and the probability is great that they won't be right unless rolling and extruding equipment of sufficient capacity and correct design are employed.

The new "blue lead" plant of the American Smelting and Refining Co. at Perth Amboy, N. J., described in this article, was laid out and built with all these things in mind. The danger of external or internal contamination of the metal was reduced to a minimum by locating the fabricating plant in proximity to the refinery and by installing equipment so large that maximum lengths of jointless sheet or pipe can be produced, and of such nature that the product is absolutely free of internal laps or seams; joints, laps and seams in lead pipe are always likely to be points of weakness, either mechanical or chemical, in service.

Also, lead is a very heavy, and very weak metal, yet its excellent resistance to sulphuric acid corrosion has fated it to be used in large, massive units—that is, under conditions that tend to aggravate these poorer qualities. In such applications as sulphuric acid chambers, the lead sheet used must have a relatively high creep strength, not only for the simple and obvious requirement of supporting its own weight without distortion, but because constant slow deformation of the lead continually ruptures the inflexible surface film of lead sulphate, on the formation, adherence and continuity of which depends the resistance of lead to sulphuric acid corrosion. The metallurgical engineers in the lead industry, therefore, have had to employ alloying elements that conferred not only chemical resistance on their products, but some measure of mechanical stability as well.

The various producers have accomplished this in different ways, and their research data on lead for chemical usage, if not already familiar to the reader, are available from them on request. A typical analysis of Asarco acid lead is as follows:

| | Per Cent |
|---|---|
| Copper | 0.060 |
| Bismuth | 0.019 |
| Arsenic plus Antimony plus Tin | 0.0001 |
| Zinc | 0.0002 |
| Iron | 0.0001 |
| Nickel and Cobalt | 0.0001 |
| Cadmium | 0.0002 |
| Silver | 0.0004 |
| Lead (by difference) | 99.92 |

The copper, present at its eutectic of 0.06 per cent in lead, increases the tensile strength from 1,740 lbs. per sq. in., as in copper-free lead, to 2,250 lbs. per sq. in. and also raises the creep stress required to cause an extension of 1 per cent per year at 25 deg. C. from a value of 200 lbs. per sq. in. in copper-free lead to more than 400 lbs. per sq. in. At elevated temperatures its creep strength advantages become correspondingly greater and its values under heavier or lighter loads decrease relatively less rapidly than copper-free lead. The bismuth content, which is also carefully controlled, is said to improve the corrosion resisting power of the sulphate coatings which appear on the surface of all sheet leads shortly after they have been placed in service in sulphuric acid solutions. The effect of other impurities in such low values as the fourth decimal place is so slight as not to be measurable.

The lead kettle shown in Fig. 1 exemplifies the type of service to which sheet lead is frequently subjected, and which it must withstand if it is to be considered a superior product. In the illustrated kettle the amount of corrosion and creep have been negligible even after 20 years of service. In contrast

# of Lead for Chemical Equipment

by FRED P. PETERS

*Assistant Editor*, METALS AND ALLOYS

to this are the very bad creep symptoms displayed by the lead sheet of Fig. 2; this picture also demonstrates very clearly the effect of creep on the surface-protecting film normally present on lead sheet. Fig. 3 shows part of the creep testing apparatus used by American Smelting and Refining Co. to investigate the creep rates of lead and its alloys—production as well as experimental material.

## Lead Sheet

The starting material for the manufacture of Asarco acid lead sheet is lead in the form of "lumps" (Fig. 4) from the nearby refinery, which are themselves the product of a 160-ton refinery kettle. The proximity of the fabricating plant to the refinery and the large size of the refinery kettles safeguard the quality and uniformity of the lumps fed to the kettle in the fabricating plant.

These lumps, which ordinarily weigh 10 tons but may in some cases be as heavy as 25 tons each, are carried by an overhead crane to the melting kettle. Each alloy (all commercial leads are actually "alloyed," even though they contain as much as 99.91 per cent Pb) has its own 60-ton kettle, two of which, turned upside down for cleaning, are shown in Fig. 5. After it has become molten, the lead is allowed to run out of the pouring spout at the bottom of the kettle into a horizontal slab mold, in which lifting hooks have been previously inserted to facilitate subsequent removal of the solid slab.

The kettle furnaces are about 18 ft. high. The kettle rests in the top, and the molten lead during "bottom-pouring" comes out at about 3 ft. above the floor level. Smaller kettles are used for remelting trimmings and clippings into "caulking lead," which is not fabricated but is sold to municipalities and others as such. Dross from the kettle and mold is returned to the refinery and re-processed as though it were ore.

The slab molds are of two types, horizontal and vertical, depending on the type of lead being poured. The vertical mold is used for antimonial lead, 3-6

*Typical copper refinery tank house, in which lead sheet and pipe are widely used. The tanks are lead-lined and the sulphuric acid solution flowing through them is conveyed by miles of lead pipe underneath.*

per cent tin-lead, and similar alloys that require very rapid chilling; the horizontal, open-top mold is employed with chemical lead and acid lead. The horizontal and vertical molds are of the same dimensions—5 ft. x 10.5 ft. x 8 in.—and the finished slabs weigh 8 tons. The dimensions of the finished slabs, however, can be modified by inserting barriers in the mold.

As soon as the molten lead has become quiet in the mold, it is skimmed to remove dross, and, when finally solid, is lifted as shown in Fig. 6 and moved to the rolling mill to be processed, either to "breakdown" sizes or directly to finished sheet. Usually, 400-500 tons of 1-in. "breakdown" slabs are kept on hand to provide flexibility in filling future orders quickly.

## The Rolling Mill

The rolling mill in which the slabs are converted to sheet is not only the most recently installed new lead mill in current American operation, but is also the largest of its kind built to date. The rolls are 32 in. in diameter, with 11 ft. between the housings. A mill of this size is really necessary if the newer and stronger lead alloys are to be processed without roll-bowing. Fig. 7 shows one of the stages in the rolling operation.

The mill, made by Farrel-Birmingham, employs no wobblers; the use of universal joints eliminates whipping and aids in avoiding the production of off-gage sheet. The rolls are of the reversing type, driven through herringbone gears running in oil baths.

Both rolls are driven in perfect synchronization, so that the "pinch" at each pass is the same on the top of the sheet as it is on the bottom. This double driving makes possible the rolling, at economical speeds, of the very hard lead alloys recently developed. The drive is a 250 h.p. D. C. motor operating from a 220-v. line, with roll speed variable between 18 and 30 r.p.m. Rolling pressures are, of course, variable, but a general idea of the pressure required, as compared with that for other metals, may be

*Fig. 1. A large lead kettle that successfully withstood 20 yrs. of corrosive service.*

*Fig. 3. Part of the creep testing room at the American Smelting and Refining Co.'s research laboratories.*

*Fig. 2. Sheet lead of low creep-resistance. This lead, unable to support its own weight, showed a creep of 1 per cent per yr. under a load of only 200 lbs. per sq. in. when tested at 87 deg. F. Properly alloyed and processed, lead will have a creep rate of 1 per cent per yr. at 87 deg. F. with a load of 420 lbs. per sq. in.*

gleaned from the observation that about 50,000 lbs. per sq. in. pressure on the roll necks is required to roll the 1/16 in. pass.

The slabs from the slab-mold are placed on the 250-ft. long roller conveyor and fed by manual-lever action to the rolls. As each slab is passed successively back and forth through the mill, a certain amount of surface lead clings to the rolls, so that it is necessary to clean the rolls during passes to prevent the formation of "laps." Impossible to prevent, however, is the lead rolling defect called "birdsmouthing," which alone causes the scrapping of about ⅓ of the mill's output. This large discard is necessary to the successful production of perfect material.

After it has been reduced to 1 in. thickness, the lead sheet is cut on a Farrel-Birmingham vertical cutter (Fig. 8) into 3 semi-finished breakdown sheets to be stored and subsequently rolled, according to customers' specifications, to finished sheet. The finished sheet is measured, chalked, scored and finally cut with a specially designed manual cutter before being shipped out for service in the chemical industry. In these last stages, as elsewhere in the processing, the greatest care is employed in handling the product; thus, the lead sheet is rolled-up on a leather belt to prevent scoring of its soft surface.

Also, the general uniformity and reproducibility of product provided by very large refinery kettles are protected in fabrication by the use of large-scale rolling equipment. The standard size lead sheet is 22 ft. long by 8 ft. wide, but the equipment has produced, on special orders, sheet as long as 90 ft.

## Lead Pipes

Of equally imposing dimensions is the extrusion equipment employed for producing lead pipe. Built by Robertson, the presses have been designed not only to provide the advantages of largest-scale operation, but to eliminate one of the most important causes of failure of lead pipe in chemical service—mechanical imperfections.

Mechanical defects sometimes found in lead pipe that are traceable to the extrusion equipment may be

*Fig. 5. Two lead-melting kettles, removed from the furnace and turned upside-down for cleaning. The kettles are made of ordinary firebox steel; note the "bottom-pouring" spout affixed to the bottom of each.*

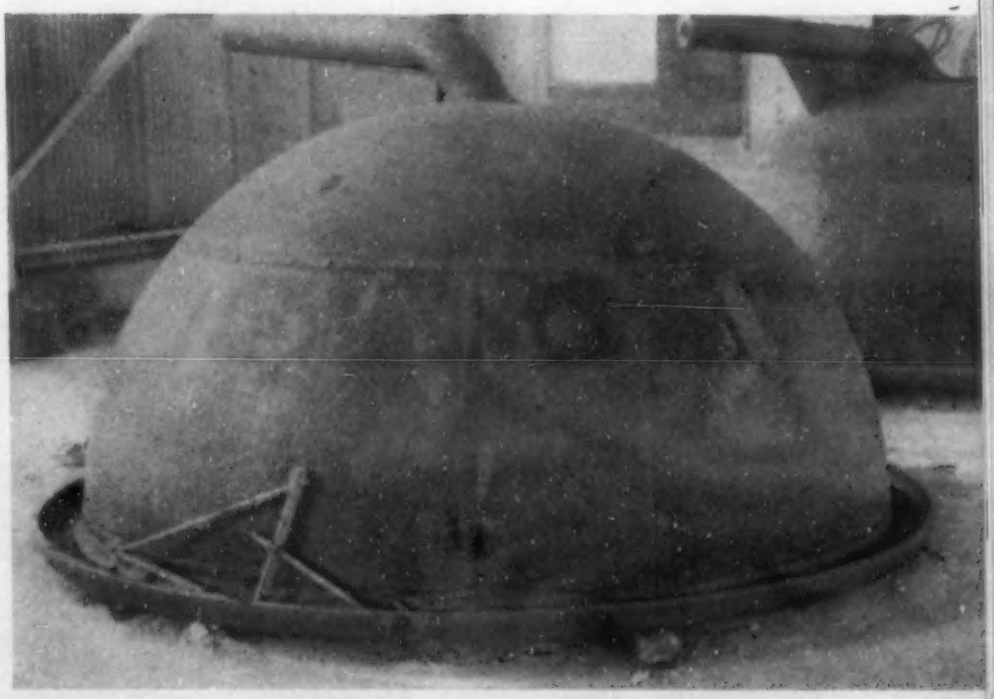


*Fig. 4. Lead lumps as received from the refinery for fabrication into sheet and pipe.*

*Fig. 6. (Below): Slab being moved from the slab-mold to the rolling mill conveyor.*

listed as follows:

(1) Eccentricity, or variation in wall thickness from one side of the pipe to the other, caused by uncompensated wear or imperfect press design. In the new A. S. and R. extrusion presses the lead cylinder travels on guided columns, so that the possibility of eccentricity in shape is reduced to an absolute minimum.

(2) Inclusions, caused not only by faulty melting and pouring practice, but by the unavoidable retention of oxides from the press-kettle in the top of the pipe. Inclusions concentrate in the top of any lead casting, but the use of sufficiently large presses means the producer can safely discard several feet from the top of each pipe without throwing away a large proportion of his production.

(3) Laminations, caused by producing a pipe greater in weight than the lead capacity of the cylinder of the extrusion press. Thus, if small-capacity presses are used for large pipe, the exhausted cylinder must be recharged with additional lead when only part of the pipe has been extruded. That portion of the extruded pipe where the 2 charges met will not be homogeneous but will contain imperfect, elongated, cold-compression welds.

(4) Invisible internal longitudinal welds, caused by attempting to overcome the foregoing capacity limitations by using a die with a short core attached by supports to its center. Under such conditions, the extruding pressure causes the lead to separate into cold strips, which, after passing the supports, are pressed together into pipe. The resulting welds extend the entire length of the extruded pipe, and are believed by many to be the lines of lowest resistance to acid corrosion.

Because presses of sufficiently large capacity would almost automatically eliminate the possibility of occurrence of most of these mechanical defects, the American Smelting and Refining Co. designed its 2 new presses along truly mammoth lines for this sort of work. The larger press is a 1500-ton unit, capable of making pipe of ½ in. to 14 in. inside diameter; the smaller press is rated at 650 tons, and can produce up to 5½-in. diameter pipe. Translated into terms of actual pipe production, these figures for the 1500-ton press mean it can accommodate cylinders large enough to make, for example, one continuous piece of 12-in. pipe with a ¾-in. wall, having a

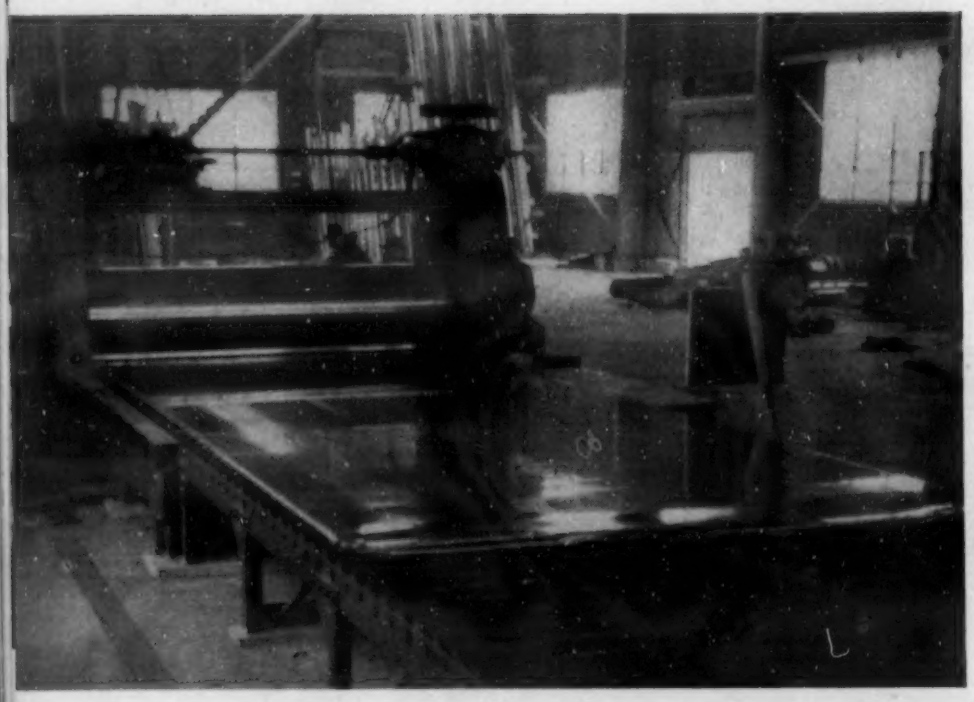


*Fig. 7. Lead sheet after about the tenth pass through the rolling mill.*

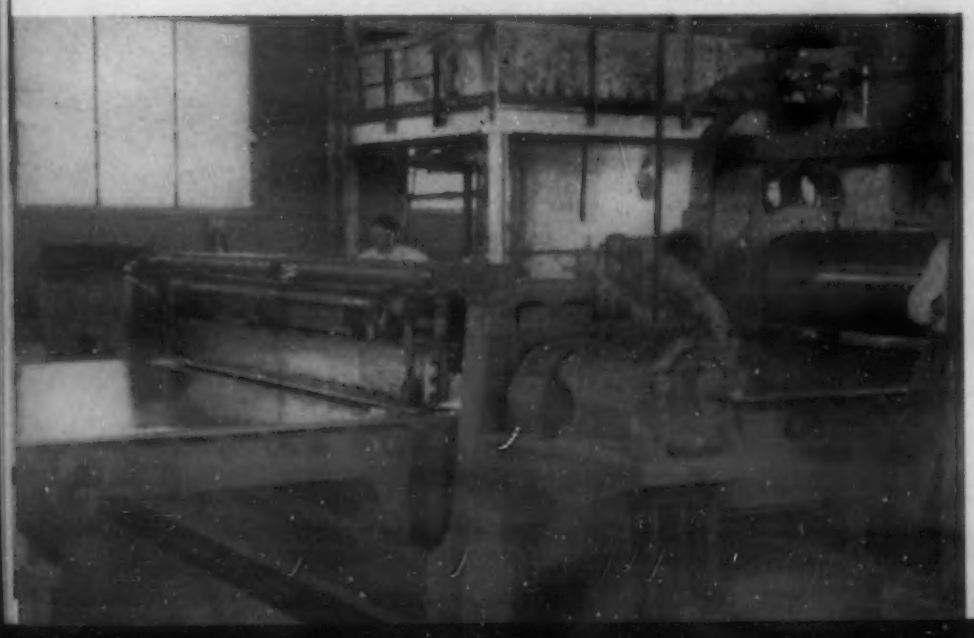


*Fig. 8. Lead sheet, 1 in. thick, being cut into 3 sections. This equipment is automatic and assures perfect right-angle cutting and absolutely straight edges.*

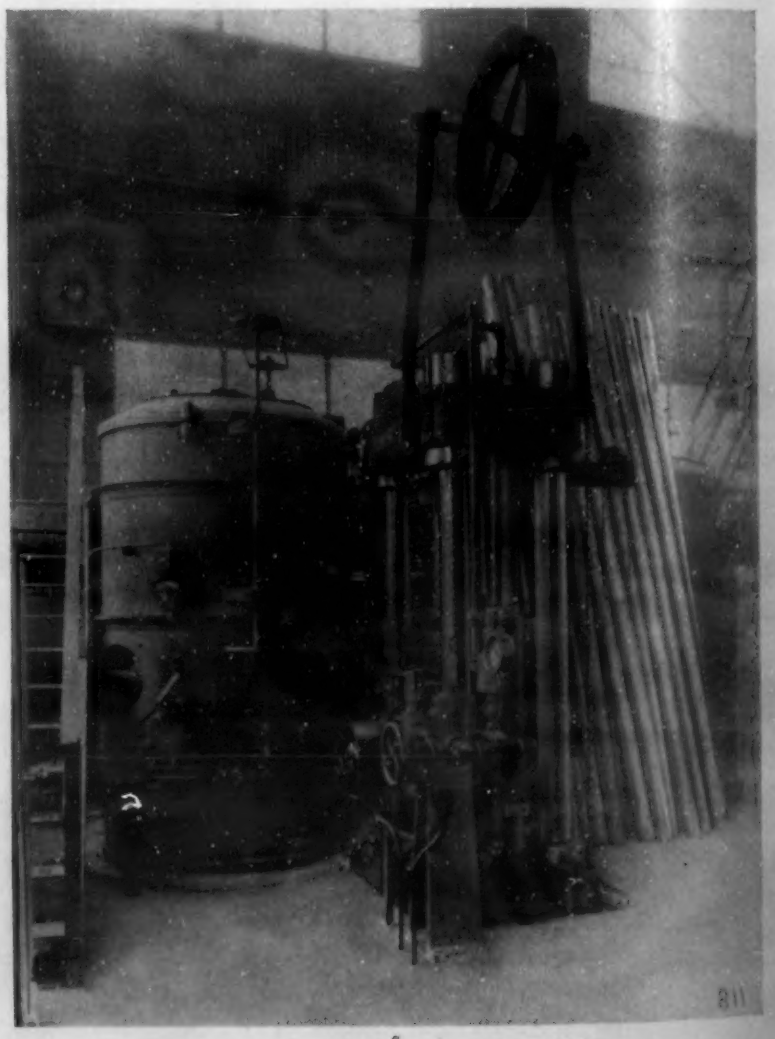


*Fig. 9. Lead-melting kettle for lead pipe extrusion press.*

total length of 22 ft., and a total weight of about 3,250 lbs. and without laminations or welds anywhere along its length.

## The Extrusion Operation

In manufacturing a piece of pipe of the size just given, the 5-ton lead kettle at the side of the press (See Fig. 9) is first charged with lead refinery lumps. The kettle is closed and heated, and the lead, when molten, is poured by means of a spout from the bottom of the kettle and a piece of connecting pipe into the lead cylinder in the hydraulic ram of the press. In the center of this cylinder there is a solid steel core, exactly centered from top to bottom, which represents and determines the inside diameter of the pipe. The lead solidifies around this core to form a short piece of heavy-wall cast pipe weighing about 4,000 lbs. Hydraulic pressure of about 45,000 lbs. per sq. in. is then applied to move the ram and lead cylinder upwards, forcing the lead and core through a die fixed to the upper part of the press. (Fig. 10, a photograph of one of the presses before its kettle had been installed and the press placed in operation, shows very clearly the core extending a few inches above the cylinder, with the die just above it.) The elongated pipe, of correct diameter and wall thickness, emerges at the top (See Fig. 11) and is carefully caught and supported, in this case, by specially designed crane-hooks 40 ft. above the top of the presses.

In the smaller diameters, unusually great lengths, usually limited only by the customer's ability to handle them, can be furnished from the new presses. When extruding such long pipe it is customary to guide the pipe over a large pulley on the top of the press and to wind it on reels, as shown in Fig. 12.

The most interesting feature of the new fabricating equipment at Perth Amboy—rolling mill as well as pipe extrusion presses—is their relatively great size for this sort of work. In the foregoing description we have attempted to demonstrate that although this "bigness" is startling in itself, it is far more important in the relation it may bear to uniformity and quality of finished product.

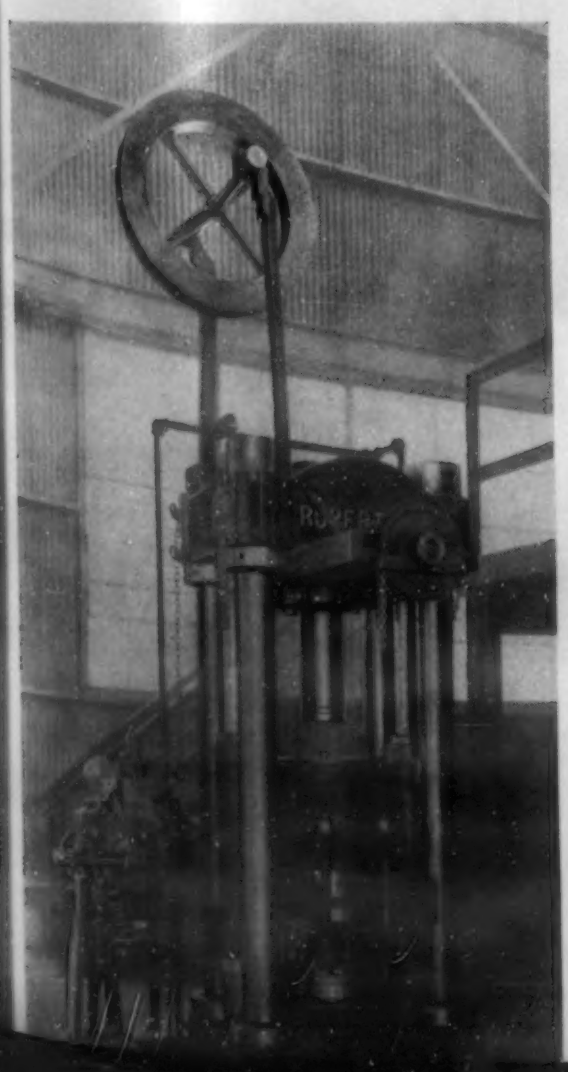


*Fig. 10. One of the hydraulic lead pipe presses, before installation of the kettle. The most important components, ram, core and die, and the guiding columns that assure accuracy of dimensions can be recognized.*

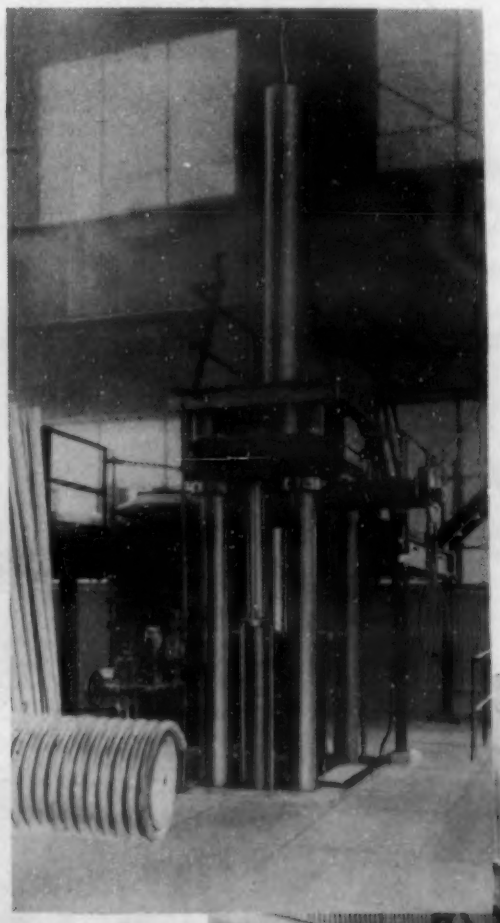


*Fig. 11. One of the heaviest pieces (3,250 lbs.) of lead pipe ever produced emerging from the extruding die at the top of the press.*

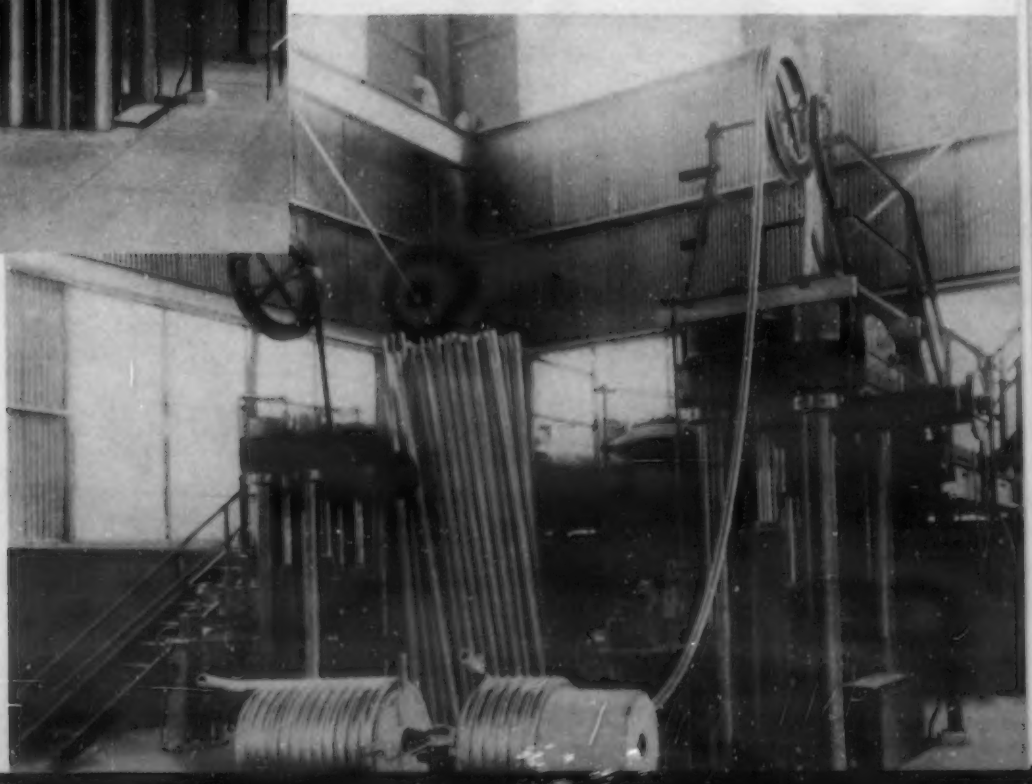


*Fig. 12. Reeling a very long piece of small-diameter lead pipe as it comes out of the press.*

*Slitting coils of stainless steel into narrow strip at the new and expanded finishing plant of the Republic Steel Corp. at Massillon, Ohio.*

# "18 and 8" and Related Stainless Steels

## Part IV · Concluded from March

by WALTER M. MITCHELL
*Metallurgical Engineer, Westfield, N. J.*

## Special Compositions

As the normal "18 and 8" alloy of iron, chromium, and nickel has not satisfied all requirements for corrosion resistance and physical properties, various modifications in composition have been introduced, and these merit attention and study.

*Carbon:* On the grounds of corrosion resistance increased carbon is harmful and the less of it in the steel the better in all cases, except where strength is desired. Its effects in this direction, particularly in raising proportional limit, have already been mentioned. Increase in carbon stabilizes austenite and, hence, decreases hardening tendency on cold working. That is, a low carbon "18 and 8" will show, all other things being equal, greater relative increase in hardness after a given degree of cold working than a higher carbon steel. While the final hardness of the high carbon steel may actually be greater, it will be because of its initially greater hardness.

The effect of carbon in causing intergranular corrosive attack after heating in certain temperature ranges has already been fully discussed, and needs no further comment.

*Nickel:* Nickel is primarily a stabilizer of austenite, and increase in nickel content is followed by an enhancement of the characteristic austenitic properties— greater ductility and less tendency to hardening by cold work. The higher nickel austenitic stainless steels are especially useful with added elements, such as tungsten, silicon, etc., for high temperature service. Additions of nickel are generally beneficial in increasing corrosion resistance, with a few exceptions; but in this direction nickel is not so powerful as other elements, notably molybdenum. Increased nickel is distinctly objectionable where sulphur bearing gases are encountered, particularly at high temperatures, and it is in such service that the high chromium ferritic steels, or "18 and 8" with molybdenum, are to be preferred. The limits of sulphur content in flue gases, as well as the maximum nickel that can safely be used in such cases, are still controversial. One point, however, remains clear, namely, that sulphur in reducing atmospheres is more objectionable than when conditions are oxidizing.

*Silicon:* Credit for the use of silicon as an alloying element is due to C. M. Johnson of the Crucible Steel Co. Beginning about 1917, Johnson investigated the iron-chromium-nickel-silicon combination and was granted patents for alloys in 1922 and 1927. The most important effect of the addition of silicon up to about 3 per cent is in increasing resistance to oxidation at high temperatures. Silicon tends to increase grain size in both the ferritic and the austenitic stainless steels, and is reported to improve welding qualities, although this latter has never been satisfactorily explained. Improvement would seem to be in a more fluid metal, and a reduction in porosity through deoxidizing properties.

The addition of silicon tends to inhibit intergranular susceptibility. As silicon is a ferrite producer its action in this direction is readily understood. Monypenny has reported the use in England of percentages as high as 6 per cent for this purpose. The necessity of heat treatment after welding is apparently avoided, and welding electrodes with this high silicon content produce deposits of weld metal that are themselves free from susceptibility to intergranular attack.

High silicon is also used in "18 and 8" as a substitute for moderate additions of molybdenum. It appears to have the same beneficial results, but at lower cost, in increasing resistance to attack from hot dilute mineral acids, but apparently is without effect against hot nitric acid or caustic alkalies. In smaller percentages the effect of silicon on corrosion resistance seems to be small.

*Tungsten:* This element was added to "18 and 8" by R. A. Hadfield who secured an English patent in 1923. This covered a wide range of compositions, including chromium, nickel, silicon, and tungsten or molybdenum. An American patent granted two years later disclosed an even greater range in compositions. The usual addition to "18 and 8" is about 4 per cent. This composition appears to have gained considerable use in England, but, so far as the author is aware, is not produced in the United States to any considerable extent, except in the form of castings. The chief benefits from the addition of tungsten are in increased creep strength, and reduced susceptibility to intergranular attack (tungsten is a ferrite-producing element). As regards creep strength, tungsten is practically unique in its action of preserving its strengthening effect to very high temperatures.

Tungsten is distinctly a hardening agent, increasing hardness, tensile strength, and yield point, and decreasing ductility. It appears to have very little effect on corrosion resistance, and is inferior to molybdenum for this purpose. As regards resistance to oxidation, or corrosive gases at high temperatures, there seems to be some difference of opinion. Some authorities fail to find beneficial results, while others —notably Hadfield—claim definitely reduced attack. Where both oxidation resistance and high creep strength are required the alloy containing both added tungsten and silicon should be considered.

## Molybdenum Additions

The addition of molybdenum to "18 and 8" was disclosed in a patent granted to Benno Strauss in

1926. The claims specifically mention increased resistance to sulphurous acid at high temperatures and pressures, and cover the composition ranges 18-30 per cent Cr, 4-20 per cent Ni, 2-4 per cent Mo, with 0.10-0.40 per cent C.

Metallurgically, molybdenum is similar to chromium and tungsten in that it is a ferrite producer. The addition of molybdenum to "18 and 8" thus tends to introduce a second phase in the alloy, which causes difficulties in both hot and cold working properties. This condition, however, can be minimized by proper adjustment of composition ratios—by keeping chromium low, nickel high, and increasing manganese to not over 2.5 per cent. Thus, there has developed a steel of the composition 15-17 per cent Cr, 12-14 per cent Ni, 2.5-3.5 per cent Mo, popularly known as "16-13-3", which is now generally supplied when "18 and 8 Mo" is specified. Such a steel is wholly austenitic.

The heat treatment of "18 and 8 Mo" must be considered more carefully than for the normal "18 and 8". At best "18 and 8 Mo" is a less stable austenitic steel than "18 and 8", and the presence of the second phase that may result from small variations in composition will affect all properties. As molybdenum is a ferrite producer it has definite action in reducing carbide precipitation, although its efficiency in this respect is not sufficiently pronounced to dispense with the necessity of heat treatment if carbon runs at all high. If carbon is maintained low (0.07 per cent maximum) heat treatment will not be necessary in many instances, the added molybdenum reducing intergranular susceptibility sufficiently for the purpose. But where strongly corrosive media will be encountered (nitric acids, or urea, for instance) heat treatment will probably be necessary. Experience shows that water-quenching from 1950 to 2000 deg. F. is most effective and that, unless properly heat treated, this steel is even more susceptible to carbide troubles than the normal "18 and 8". Owing to the sensitiveness of this steel to variations in composition ratios the proper heat treatment for a given analysis might well be determined by preliminary investigation.

To avoid the necessity for heat treatment, and to secure complete freedom from intergranular susceptibility, *e.g.*, where stress relieving treatment might be necessary or after welding operations, columbium has been added as a further stabilizing agent. On theoretical grounds such a composition would appear desirable, provided excess columbium is avoided. The added stabilizing element would avoid the necessity for rapid cooling after annealing and either heavy or light sections could be air-cooled without injury. Claims are made that this complex steel has less tendency to pitting and contact corrosion in brines, sea-water, etc. The alloy appears to be difficult to handle in mill operations, as might be expected from its composition.

Molybdenum is similar to tungsten in increasing tensile strength and hardness of "18 and 8" at both room and elevated temperatures, but it is not so effective in this respect. It lowers ductility in cold metal and definitely increases creep strength. It appears slightly beneficial in increasing oxidation resistance, especially in the higher temperature ranges.

But it is in the beneficial effects on corrosion resistance that molybdenum is the most valuable of the alloying additions. It definitely increases corrosion resistance against many chemicals, and apparently never reduces it. Rather curiously corrosion resistance of the modified "16-13-3" analysis seems to be inferior to the authentic "18 and 8" ratio with 3 per cent molybdenum added.

Molybdenum increases resistance against many materials, particularly sulphurous acid and sulphite liquors, sodium and calcium brines, hypochlorite solutions and the phosphoric acids. It notably increases resistance to dilute sulphuric acid, both hot and cold, to boiling acetic acid and acetylating mix-

*Wrought into a spectacular structural design which seemingly defies the force of gravity, this structural steel fountain is the centerpiece of the Edward G. Budd Mfg. Co. exhibit at the New York World's Fair. The high tensile strength and adaptability of stainless steel in fabrication make the structure possible. (Courtesy Edw. G. Budd Mfg. Co.)*

tures, to formic, oxalic, and tartaric acids in all concentrations and temperatures. The increased resistance to some of the latter acids has been applied advantageously in textile industries for dyeing and bleaching equipment. Such solutions are made up with small additions of various organic and mineral acids and are used almost boiling hot. "18 and 8 Mo" has been found quite satisfactory for such usage, while normal "18 and 8" and Monel metal have not given good results.

The effectiveness of molybdenum in increasing

corrosion resistance against sulphur compounds is well demonstrated by results of tests that were conducted by one of the Eastern railroads with authentic "18 and 8 Mo" exposed to locomotive smoke in a round house. Samples of sheet of various analyses showed loss in weight after exposure for 2 periods of 8 wks. each, as follows:

| Steel | 1st Period | 2nd Period | Average |
|---|---|---|---|
| 18 and 8 Stabilized Ti | 1.9% | 5.9% | 3.9% |
| 18 and 8 | 2.9% | 5.2% | 4.1% |
| 25 and 12 | 1.4% | 3.5% | 2.5% |
| 18 and 8 Mo | +0.4% | 0.4% | 0.0% |
| 17 Cr | 3.9% | 7.5% | 5.7% |
| Copper Steel | 43.1% | 49.6% | 46.4% |

Rust and all foreign deposits were carefully removed before each weighing. For comparison a sheet of typical "copper-bearing" steel was included in the tests. While the accuracy of the tests is probably not too great, the trend of superiority of "18 and 8 Mo" over normal "18 and 8" and "25 and 12" is shown consistently. The "25 and 12" steel is somewhat disappointing in corrosion resistance in view of its high alloy content.

In the paper and pulp industry there is much experience favoring the addition of molybdenum. The Materials of Construction Committee of the industry is generally favorable to the addition of some 4 per cent Mo in chromium-nickel austenitic steels. Normal "18 and 8" seems to be at the low margin of corrosion resistance under conditions of sulphite mill operation, and specifications for castings call for a minimum of 20 per cent Cr, 9 per cent Ni, and 4 per cent Mo. Such castings will obviously not be wholly austenitic in structure, but if used as such, and forging is not attempted, no difficulty should result.

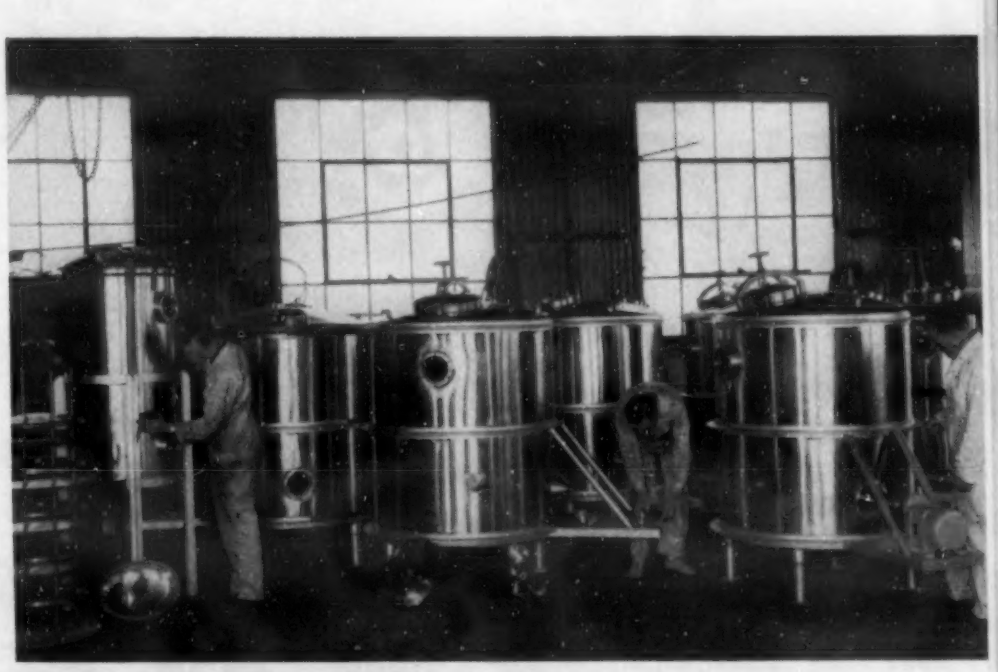
## Other Alloying Elements

*Copper:* The addition of copper was disclosed in another patent, granted to Strauss in 1925, which claimed resistance to ammonium chloride solutions, and covered alloys within the range of 18-24 per cent Cr, 7-20 per cent Ni, 2-6 per cent Cu, and 0.1-0.4 per cent C. Copper appears to be beneficial in providing increased resistance to acetic and hydrochloric acids, brines, etc. While austenitic steels containing small percentages of copper, or copper and molybdenum, are listed commercially, the author is not aware that they are produced in other than very small tonnages. A steel with copper and manganese in place of nickel has been proposed and, if reports of its properties are confirmed, should enjoy some popularity.

*Manganese:* This element, since it functions somewhat similarly to nickel as a producer of austenite, has been suggested by F. M. Becket as a substitute in part for nickel. Becket gives interesting figures and properties for these steels, which have been further supplemented by the work of Burgess and Forgeng acting under his direction. Becket's original patent, granted in 1920, specified the following composition ranges, 10-45 per cent Cr, 3-25 per cent Mn, and Si and C each 0-3.0 per cent.

Used in small percentages (up to 2.5 per cent), manganese is useful in improving the hot working qualities of the special "18 and 8" steels with molybdenum, titanium, or columbium. Like nickel, when added to "18 and 8" in larger quantities, it promotes the formation and hence the stability of the austenite; it is, however, distinctly less powerful than nickel in inducing and maintaining a completely austenitic structure. While the steel with 18 per cent Cr and 8 per cent Ni can be made completely austenitic, the steel with 18 per cent Cr and 8 per cent Mn cannot be made completely austenitic by any method of heat treatment. Hence, to supplement the action of manganese, additions of nickel or copper, or both, are sometimes made.

The iron-chromium-manganese steels have been found to have good ductility and are useful, where,



*Fruit juice tanks of stainless steel at the plant of the Nesbitt Fruit Products, Inc., Los Angeles, Cal. (Courtesy: Republic Steel Corp.)*

because of economic conditions, nickel is not available. Corrosion resistance is generally inferior to that of the 18 per cent Cr 8 per cent Ni composition, with the exception that for exposure to sulphurous and sulphide gases the steel with manganese in place of nickel has some advantages. Unfortunately, it is not free from susceptibility to carbide precipitation. From all the data thus far obtained, it would seem that the chromium-manganese steels cannot be substituted out of hand for the normal "18 and 8" with nickel.

Other elements, such as aluminum, vanadium, cobalt, etc., alone, or in combination, have been proposed as additions to "18 and 8", and various

hybrid steels made up experimentally. But until more data regarding their properties—good or bad—become available, not much can be said for or against them.

## Free-Machining Steels

Austenitic "18 and 8" has never been distinguished for its easy machining qualities, and much inconvenience has resulted therefrom. To overcome this condition sulphur has been added, as in Bessemer screw stock. Then to overcome the objectionable qualities resulting from high sulphur—notably red shortness—other elements, such as zirconium or molybdenum were added in small quantities. The Carpenter Steel Co. has been chiefly responsible for pioneering this development, and has marketed a "free-machining," or non-seizing, straight chromium steel containing sulphur and zirconium, for which a patent was granted in 1931. Apparently sulphur was not altogether desirable, for a second patent, granted a year later, disclosed the addition of selenium, or tellurium, in place of sulphur (all three are members of the VIth Group of the Periodic System), which, it was claimed, avoided the objectionable effects of sulphur, and against which there was less prejudice. This patent discloses an alloy containing 4-60 per cent Cr with selenium or tellurium, or both, of a total percentage between 0.3 and 2.0 per cent, characterized by relatively free-machining quality. Other alloy additions are mentioned in the specifications, as "silicon, copper, molybdenum, tungsten, and with nickel additions even sufficient to produce an austenitic product."

The "free-machining" steels have achieved very considerable popularity, as they provide a distinct gain in machining qualities. Practically all "18 and 8" bar stock now marketed is free-machining grade.

## Future Developments

The discussion has so far covered the more customary variations of the "18 and 8" composition. What the future will evolve is a rash prediction, but it seems probable that the more complex types of stainless steels will receive much consideration. The two defects from which "18 and 8" suffers—carbide precipitation and pitting corrosion—are losing their terrors. Carbide precipitation troubles, thanks to columbium or titanium additions, are largely overcome. Pitting corrosion is, however, still without a proper remedy, and experiments with alloy additions, or other means, will undoubtedly be directed towards overcoming this problem. Other than this, research will probably be carried out to improve mechanical properties, simplify fabricating problems, and develop increased corrosion resistance against certain chemical media.

It is a comparatively simple matter to produce a new alloy by indiscriminately combining a number of metallic elements. But it is an entirely different matter to determine whether it will be useful or not. There is usually a balanced ratio, which provides that the new alloy will have reasonable mechanical properties and, what is essential, properties that make possible its production in such forms as are necessary for chemical or engineering equipment, or otherwise. Unfortunately the complexity of ternary, quaternary, and higher alloy systems, and our present deficiency in knowledge concerning them, make difficult any prediction of the characteristics of a given combination. This applies particularly to mechanical and hot working qualities, and makes necessary the development by tedious experimentation of the proper heat treatment or processing required to produce best mechanical or other properties in the alloy.

With respect to the prediction of corrosion resistance we are better equipped, but in a general way only. We do know that the various metals in sufficient proportion impart their specific resistance to alloys to which they are added; for instance, chromium imparts resistance to oxidizing compounds, many organic acids and to sulphur compounds, nickel to caustic alkalies but not to sulphur compounds, nickel and copper to reducing acids, silicon to mineral acids but not to caustic alkalies, etc. Thus, in a general way, we can make a scientific guess as to the class of chemical media that a new combination can be expected to resist. But further than this we cannot go at this time, and if accurate information is desired on the resistance of the new alloy to some of the infinite combinations of chemical compounds as affected by conditions of concentration, temperature, aeration, and agitation, we have no other recourse but experimentation under conditions simulating as closely as possible those under which the metal will actually be used. This is a time-consuming and costly procedure, but at present there is no satisfactory alternative. However, experience is being rapidly accumulated, and each year adds to our total of knowledge, so that some day we may be able to select the alloy for a given service without undue difficulty—provided chemical and engineering requirements have not advanced too greatly in the interval.

# Letters TO THE EDITOR

## Failure of Low Carbon Steel Still Tubes

*To the Editor:* Wright and Habart (*Metal Progress,* Vol. 34, Nov. 1938, pp. 573-578; Dec. 1938, pp. 685-688) comment that intercrystalline failures of low carbon steel still tubes appear to occur only under very unusual conditions. Until quite recently we were in entire agreement with these statements. However, several failures have come to our attention which lead us to conclude that intercrystalline failure in low carbon steel still tubes in service is not as uncommon as we had previously believed. Photographs showing one of these failures are presented herewith.

Fig. 1 shows the type of rupture which occurred (the tube on the left being the low carbon steel tube under discussion.)

Fig. 2 shows the microstructure in the vicinity of the rupture. This represents one of the best examples we have ever observed of intercrystalline cracking in actual service.

The data submitted to us in connection with this failure are as follows:

| | |
|---|---|
| Life | 40 months |
| Temperature of oil | 880 deg. F. |
| Temperature of metal (estimated) | 910 deg. F. |
| Temperature of furnace | 1,355 deg. F. |
| Oil pressure | 725 lbs. per sq. in. |

The metal of the failed tube showed the following physical characteristics:

| | |
|---|---|
| Ultimate tensile strength | 47,950 lbs. per sq. in. |
| Yield point | 29,350 lbs. per sq. in. |
| Reduction in area | 76.7 per cent |
| Elongation in 2 in. | 43 per cent |
| Rockwell "B" Hardness | 58 |

R. W. Moore.

Socony Vacuum Oil Co.
Brooklyn, N. Y.

*Fig. 1. Above: Ruptured Still Tubes: This shows the brittle rupture of the low carbon steel tube (left) and the incipient crack starting from the inside of the tube in a low carbon plus 0.50 molybdenum tube.*

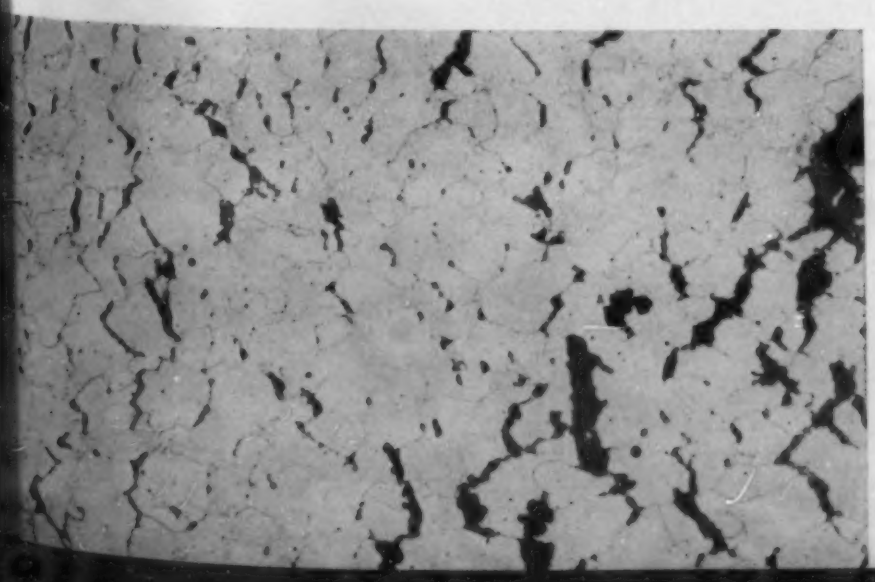


*Fig. 2. (Left): This shows the structure of an area about 1/8 in. from the O.D. and 1/8 in. from the fractured surface of the low carbon steel tube. Etched with 3 per cent nital. 100X.*

## Comment of Mr. Wright

The following comment from a letter to Dr. Moore is of interest.

The information contained in the letter of Dr. R. W. Moore is very significant as this is our first experience with a low carbon steel tube which has ruptured in an intergranular manner.

Your report does not give the tube dimensions so I am unable to calculate the pressure stress which would have developed in the tube wall. The physical appearance of the fracture of the carbon steel tube indicates to me that it is of the creep-to-rupture type. I notice that the tube has been in service approximately 28,800 hours. The tube has expanded a very considerable amount—I would judge approximately 20 to 25%. It has been our experience that tubes failing at high temperature usually expand about 25% with considerable thinning of the wall and a ductile fracture. I wonder if this carbon steel tube failure did not occur due to a hot spot on one side. If the tube metal temperature had been normal for several thousand hours, the stress in the tube would have been more of the order of a creep stress, and the expansion of flow of the tube a creep phenomenon. If, however, the tube develops a hot spot with a temperature 200 or 300° above the normal metal temperature, such as 1100 to 1200° F., the stress in the tube wall would be such as to develop a creep-to-rupture condition at such temperatures which might rapidly develop a non-ductile intergranular fracture. We know now that in conventional tensile creep testing, if the stresses are high, non-ductile fractures can be developed. At the present time we feel that these stresses must be two to three times the ordinary tensile creep limit of the steel at the temperature employed in testing.

I notice in the photomicrograph that the steel structure is almost totally decarburized. The structure is also very similar to that which we often encounter on steel tubes subjected to the action of hydrogen. It has always puzzled me why the hydrogen which develops in cracking operations does not exhibit more of this effect than has been reported. It is quite possible that in certain reforming or alkalization processes that a considerable partial pressure of hydrogen might be developed. As far as I know, no one has ever determined what partial hydrogen pressure might be critical in developing a hydrogen embrittlement. I would be interested to know if you have any idea as to the proportion of hydrogen which might be developed in the cracking of different oil fractions.

E. C. Wright
Chief Metallurgist

National Tube Co.,
Pittsburgh

*Editorial Comment:* In this connection one might consider also the "shattercracking" part that hydrogen itself might play, apart from its decarburizing effect. Compare the correlated abstract on hydrogen, the first installment of which appears in our May issue.

# EDITORIALS *(Continued from Page A33)*

## Scrap Steel Exports

Publication recently of what are evidently Government statistics of the export movement of scrap in the *American Metal Market* makes it possible to review the situation during the last 7 years. The complete data cannot be repeated here; only a few of the highlights, in which Japan plays the important role, can be cited.

Total exports in 1939 at 3,577,427 gross tons were second only to 1937 in the 7-yr. period, 1933 to 1939. But last year Japan took 2,026,006 tons or 56.6 per cent of the total, her largest total of the period. Italy's 1939 purchases of 425,896 tons were second to her 1938 total, while the 508,293 tons sent to the United Kingdom last year were second to the 845,216 tons taken in 1937.

The heavy movement of scrap to Japan began in 1933 when she took 70 per cent (547,539 tons) of the then small total exports. In the 7 years her purchases have increased nearly 4-fold. Of the 17,317,275 tons of scrap exported in the 7-year period, Japan has taken 9,204,204 tons or 52 per cent—an impressive tonnage.

Consumption of scrap in the United States during the 7-year period is put at 193,330,669 tons. Of this the total exports have been about 9 per cent or 17,317,275 tons. Last year the exports of the total consumption were also about 9 per cent with the 1937 proportion 9.7 per cent. In 1938 this figure was 12.4 per cent.

This very heavy movement of scrap out of the country has two important features. First, there are those who insist that the exports tend to rob our own resources. Probably sales abroad of an average of about 9 to 10 per cent of our consumption are not serious. Second, Japan's use of these exports. They are a potent factor in that country's military aggression in China. Hence the use to which they are put is one argument for an embargo.—E. F. C.

# A Few Chuckles

## Tempering a Barrel

From the *Outdoorman*, Feb., 1940

Q. I recently read an article which stated that a rifle should be shot about 40 fast shots and then while hot, have a 15 per cent salt solution in water poured through the barrel to set the barrel. Is this true?

J. B. K., Kansas City, Mo.

A. I have never heated up any of my own rifles or given them a salt bath. Jim Howe who recommends such treatment is a wonderful gun smith, probably as good as any in this country and also understands metallurgy thoroughly, so may be right in his claims for this treatment. I have never wanted to chance warping the fore end of a fine stock, or putting this amount of water on a fine barrel, so have never tried the salt water treatment. I do know that many rifles do not settle down to business until they have been warmed up by firing and their guard screws thoroughly tightened up, but I am not capable of sitting in judgment on the salt water barrel hardening process. I have owned and now own many fine rifles that shoot perfectly that were never so treated.

M. L. WEISS

1020 Alabama St.,
San Francisco, Cal.

## Metals in Coins!

*To the Editor:* The attached clipping is submitted for the "Metallurgical Chuckles" department.

"Aluminum and Bronze now form one of the most popular alloys for coinage in the world."—*N. Y. Times Magazine*, Feb. 5, 1940.

I understand that Monel and Metal also make a very excellent alloy.

J. L. CHRISTIE
Asst. to the Vice President.

Handy & Harman
Bridgeport, Conn.

## New Bearings and New Lamp Filaments!

Our attention has been called to the following extracts from Merck's *Index* in an edition just published:

Babbitt Metal—Alloy of 69% Zn, 19% Sn, 4% Cu and 5% Pb. Used for machinery bearings.

Cadmium—Uses . . . deoxidizer in Ni plating . . . electrodes for Cd vapor lamps . . . filaments for incandescent lamps.

Osmium—Uses—chiefly as alloy with iridium for . . . fine machine bearings.

Palladium—In form of gold, silver and copper alloys in dentistry, in journal bearings.